

# DISCOVERY

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## The Progress of Science

A MONTHLY NOTEBOOK COMPILED UNDER THE  
DIRECTION OF DAVID S. EVANS

### Time, Place, and Conditions

THE prelude is over. Before very long the curtain may be rung up on the main drama of the Battle of Europe. Where do the scientists come in to this struggle? Theirs is the work which goes on unobtrusively in the background. They are the men and women whose task it is to see that the weapons are fit for their purpose, that the aircraft and ships, the guns and the tanks, the shells and the bombs will act as required at the right moment. They fight with their brains and the skill of their hands, anticipating and moulding the future, foreseeing possibilities and countering them in advance.

This war is changing the traditional ways of science and scientists out of all recognition. They are entering fields which no one thought were the province of science. Their mental outlook and the flexibility of their scientific technique have broadened enormously. Up to the beginning of the war highly qualified scientists coming from universities very often retained a slightly academic approach, which thought of physics and chemistry and mathematics as things in separate compartments that might be applied only to subjects which looked like the usual text-book topics in those sciences.

To some extent they even ignored the most potent weapon of all, a weapon which is hardly ever deliberately forged by formal academic instruction, but which it is assumed will be picked up by the wayside. This weapon is the scientific method. It means the ability to think adventurously but precisely. It means intellectual integrity which never hesitates to discard favourite theories the instant they fail to square up with facts. It means the ability to probe any situation and to extract from it those factors which are of dominant importance, while remembering that those factors may, as the situation changes, lose their dominance to others which are at the moment of minor importance. It is a method of universal applicability, which, once understood, is of equal value to the problem of learning to drive a car, fire a gun, or hang a picture, as it is in the disentangling of the properties of

atoms. Erudition does not make the scientist. The one essential is the knowledge of how to think, and the ability to use the scientific method.

The shocks of war have taken our young men from the shelter of the universities and have put them into armies and onto airfields, into factories and workshops. There circumstances are bringing them into contact with new problems which are not in the text-books, as well as new people who are not in the charmed and closed circle of scientific speciality.

The most spectacular of the new advances has been the development of operational research, by which is meant the study of the behaviour of weapons, machines, and even the men who work and fight with them, under the actual conditions of battle. It is an application of the scientific method to what have become ordinary, everyday affairs. It is the simple but vital business of keeping square pegs away from round holes both in the human and the mechanical fields. The success of the application of science in such problems may perhaps shock the academic mind of the type of Flexner's, who condemned the award of a degree for a study of the technique of dish-washing. We, too, may condemn that, not because of the triviality of the subject—and indeed there are few human activities more productive of misery and more universal in scope than dish-washing—but because it was not a very competent thesis. It will nevertheless be a great stride forward, if in the days of peace we can retain this notion of the applicability of the scientific method to everyday affairs, and can go on to use it to alleviate the lot of the workers in our key industries, among which domestic labour must certainly be included. Those who deplore so great a departure from the fold of traditional "pure" science may console themselves with the reflections that science always has developed in this way, and that if it is good science it will, in its turn, lead to the development of new fields of pure research as yet unthought of.

This war has introduced the scientist not only into new fields of investigation, but has brought many among his calling into working fellowship with new kinds of people.

In the one common effort to raise the level of production the scientist becomes the direct personal ally of the man at the bench, and, at first perhaps in only a few firms, he now finds himself taking part in the work of Joint Production Committees as a representative of a particular part of the skilled staff. This is operational research on the co-operative basis. It is the study of the process of production as a whole, and the scientific analysis of the varied factors contributed by different sections of the membership of the Joint Production Committee so as to secure the single common aim.

This is a new experience for many scientists, and one which bridges the gulf between a specially highly skilled section of the workers, which was formerly cut off from the vastly greater body of their fellows. The modern scientist in industry is losing his sense of discomfort at belonging to a trade union, and is realising with pride that to regard himself as a fellow of the worker at the bench is not to degrade his status, but to make the more readily available the knowledge which he has so long and so passionately wished to see fully utilised for the benefit of the community. Far from finding that his trade union contacts restrict him, he is discovering that they give him new and exciting opportunities, and enable him to take his place as the technical adviser to the community. He can do this not only through his Joint Production Committee but through other organs of the trade union movement. Some scientists are now members of Trades Councils, and are finding that this membership enables them to bring special knowledge to the place where it is needed and can be utilised. As the accepted organ of the organised workers, the modern Trades Council has much to say in the work of local food committees, in the regulation of local hospitals, and in the provision of new health measures such as mass radiography for workers in factories. Here is the golden opportunity for the scientist to win confidence of the vast majority of the nation—and it needs to be won—in the possibilities of the application of science.

But this is only one aspect of the activities of trades unions. How are scientists affected by the aims of the trades unions for the improvement of rates of pay and working conditions? In so far as satisfactory working conditions are essential for optimum production, this is directly related to the overriding immediate task of securing maximum production to shorten the war.

It is essential for this aim that many long-standing abuses of the conditions of scientific employment should be removed. The old bad system of the transference of any patent to the employer for a nominal sum should be abolished. Perhaps even more galling is the habit in some establishments by which the younger worker is robbed of his due credit by the publication of work under the sole name of his superior. The grossest abuse of all is the discrimination against the woman scientist. There might perhaps be an arguable case for a lower rate of pay for a woman in a manual occupation where physical strength is of some importance, but the performance of women in industry has scouted this argument completely. There can be no justification for the assumption that a woman doing a job of a severity equal to a man's will do it 10% worse, and is therefore worth that much less in salary. The woman scientist has competed on equal terms with men in gaining her qualifications, and does a man's work. It is

unjust that she should receive a smaller salary, and inhuman that if she is injured her compensation should be less.

Today the workers of Britain have but one aim in mind: to back up their armed forces and to shorten the war. The recognition by the scientist of his honourable place in their ranks will hasten the attainment of that aim.

## Service Scientists

THE young men who go into the ranks of the modern fighting services need far more equipment of technical knowledge than their predecessors ever did. Our Universities and training colleges are meeting the need by the establishment in conjunction with the service authorities of short courses for Army, Air Force and Naval cadets. The object of these courses is not only the provision of instruction in a narrow technical speciality, but also the attempt at the development of some of the mental flexibility and adaptability which a good education produces. The problem of attaining any results in only six months is a severe one. Most of the cadets are aged seventeen and have taken their school certificate examination before arrival at the University. In one University the experiment has been tried of basing such liberal education as can be provided in this very short period entirely on the sciences. This is a clean break with the tradition which all too often regarded the humanities as the exclusive means of liberal education, and the sciences as mere technicalities suitable only for vocational training. To devise a course of instruction based on a single science, for pupils who start almost from scratch, and whose time is short and fully occupied, and still to give them some inkling of the scientific method and of scientific thinking, has needed very considerable care.

The idea of exhaustive instruction has naturally had to be abandoned, both for lack of time and because of the state of comparative unpreparedness from which it is necessary to start. Any over-crowding of courses might even be disastrous, since the mere cramming in of knowledge might all too easily destroy the one great asset which this new type of student possesses—his enthusiasm and eagerness to learn.

In the instruction of R.A.F. and Naval Cadets one—at first sight rather unpromising—speciality has provided particular scope for this type of education. This subject, astronomy, is necessary for the technical equipment of the navigator, but its more advanced parts provide at the same time the possibility of an introduction to science for students who have never had any previous scientific experience.

The pitfall of mere vague generalities was avoided because it was necessary for each cadet to have a thorough understanding of the fundamentals of spherical astronomy which are essential for navigation, but even this had to be taught by a technique different from the usual one, for it was most desirable, before embarking on what might have seemed a pointless mathematical deduction, to secure the intellectual conviction that it was possible to determine position on the earth's surface by observations of the stars.

Once this section of the work had been thoroughly grasped it was possible to proceed to the more modern

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R.A.F. students learn how a telescope works.

Fox Photos, Ltd.

parts of astronomy. Here an outline course was covered, which always laid heavy stress on the scientific methods by which knowledge has been attained, and emphasised that new knowledge is not to be gained from books but from experiment and from the observation of nature. This was a new idea to most of the students, and was the means of securing their interest and of stimulating their enquiries and questions. As a final stage, in order to give each student a thorough knowledge of one section of the subject, a system of lecturettes was introduced. Each student drew a card from a hat, on which a subject and a suitable reading list were given. He then had to prepare a short ten-minute talk on this subject, using lantern slides and diagrams as inclination suggested. The results were extremely good. There was a general air in the class of giving the victim a fair chance, and the lecturers were listened to with great attention. The standard of the lectures was extremely high, and included some which would match anything ever encountered elsewhere. At the end, the rest of the class fired off questions, the instructor being at hand to counter those of especial difficulty or others which were definitely below the belt. These methods of instruction seem to have resulted in the development of a real scientific interest, and there seems to have been real enjoyment and enthusiasm among the students. Perhaps the emphasis on a spirit of scientific scepticism was a little too great, but that its importance

was realised is shown by a quotation from an examination paper, "Very little is known about planets, and there is good scope for keen types who wish to study them." There is indeed.

## The Magnetic Properties of Rocks

THE study of the general magnetic field of the earth, and of the local variations produced by the presence of various deposits of ores, has been of the greatest importance not only for theoretical reasons, but also for the practical business of geological surveying and prospecting. However, very much more work needs to be done on the possible ways in which various types of rocks may have acquired their magnetic fields before many of the details of rock formation can be filled in, and a complete interpretation of the results of magnetic surveys obtained.

It is for these reasons that the recently published results of experiments on the magnetisation of rocks by Herroun and Hallimond are of importance. Their experiments were carried out on a number of rock samples, some collected from areas which have already been covered by magnetic field surveys and whose original locations ranged from various parts of Scotland down to Leicestershire. It is known that many of the observed magnetic anomalies can be explained if it is assumed that the magnetic field of rocks has been partly induced by the present field of the

earth, and is partly due to a magnetic field acquired earlier. The object of these experiments was to see what intensity of magnetisation could be induced in the rock samples under a variety of conditions.

The first set of experiments was intended to study the magnetism acquired by a rock sample when cooling from a red heat in the earth's magnetic field. It is known that heating to redness destroys the magnetism of practically all rocks, but if, during the process of cooling, the rock is subjected to an external magnetic field, such as that of the earth, a certain order will be introduced into the molecular arrangement of the sample, and will result in a permanent magnetisation.

Cubes of one and a quarter inches in size were cut from the rock samples. These were then placed in an earthenware pot and surrounded with iron ore. The object of this was to protect the cubes from the oxidizing action of the air, and to simulate natural conditions as far as possible. The cube was placed level, and one edge was pointed in the direction of magnetic north. The pot and its contents were next heated in an electric furnace having no iron fittings, and after about an hour at redness allowed to cool. The protection of the specimen from oxidization was not complete, and there was some change due to the action of the steam liberated by the specimen itself, but this could hardly be avoided. When the specimens had cooled their magnetisation was measured, and it was found that this had greatly increased. Moreover, the specimens afterwards retained their magnetic properties, and even after four months showed no appreciable change.

The behaviour of specimens in the cold was quite different. Here a very large field was needed to induce the same magnetic intensity, and even then it was not permanent but died away slowly. Weak fields had no effect at all; and it was interesting that a field as weak as that of the earth produced no magnetisation, so that it is clear that samples of magnetic rock can be moved on the earth's surface without danger of altering their magnetic properties. Higher fields than the minimum produced rapidly increasing magnetisation; but it was found that if a specimen once magnetised in this way was then subjected to a second field at right angles to the first, the two effects did not reinforce one another, and that the second magnetisation actually produced a reduction in the magnetisation which had been induced first.

Comparing these results with the observations of rocks which are naturally magnetised, the authors found that certain rocks have a natural magnetisation as great as that which would be produced by cooling in the earth's field. It therefore seems clear that such rocks must have become magnetised during a cooling process, for to produce the same result in the cold would require, allowing for the decay of magnetisation induced in this way, a field between ten and thirty times as great as the present field of the earth. An additional argument for this is that if the magnetisation had been produced by some magnetic field outside the earth, this hypothetical field must have acted for only a very short time; for otherwise the rotation of the earth on its axis would have changed the direction of the magnetising field, which, as the experimental results showed, would not have increased the magnetisation but have tended to destroy the magnetisation produced initially.

## The Nutrition Society

EXPERTS in the field of infant nutrition gathered at the London School of Hygiene and Tropical Medicine on Saturday, May 23rd, to discuss the problems of the feeding of babies.

The topic which received greatest attention by the various speakers was the importance of an adequate supply of vitamin D to the infant, and particularly to the premature infant. A baby which is born before its time grows very rapidly, and needs more food relative to its weight than one born at full term. Both for this reason and because it has no stores of calcium it may be predisposed to the development of rickets if there is a deficiency either of calcium or of vitamin D in its diet. Vitamin D is essential for the proper assimilation of such calcium as may be available, and it is therefore important that an ample supply of the vitamin should be given as early as possible to a premature baby.

Even a baby born at full term needs a large supply during the first six months of its life, for this is a period of especially rapid growth and of bone formation. A dosage of from 400 to 700 International Units per day is desirable, which is equivalent to one or two teaspoonfuls of cod-liver oil. It was recommended that this dose should be given as a routine measure whatever the season of the year, even though the production of vitamin D by the irradiation of the skin by the ultra-violet component of sunlight is more effective in summer than in winter. This latter source should be sufficient even in winter to prevent severe rickets provided that the baby is taken out, but there is the danger that a baby who has been ill may be kept in for a week or two afterwards. The speakers were emphatic that the only safe way of keeping out of trouble was by routine dosage with cod-liver oil.

Several speakers were extremely emphatic in scouting the idea of the alleged dangers of hypervitaminosis D, or excess of the vitamin. Professor Morris, of Glasgow, described the idea as nonsense and said that references to it should be expunged from the literature. His contention was supported by three speakers, who said that they had given daily doses of half a million or more units of vitamin D to patients suffering from various complaints with no ill effects whatever.

Another topic of discussion was the vicious circle which may be produced by under-nutrition and infection. Under-nutrition may lead to a lowered resistance to infection, and infection can result in under-nutrition. A condition such as for example latent scurvy can in this way be changed into active scurvy. Once such a circle has been set up, it cannot be broken by treating only one of its parts. For instance if an infection in a child leads to anaemia this cannot be cleared up simply by treating the anaemia, with for example iron tonics to which it normally responds, but the infection must also be removed.

One speaker attacked the advertisements of patent baby foods, which, he said, sometimes led poor mothers to spend as much as 6s. or 7s. a week on foods which were either of little value or unnecessary for the baby, and he advocated the control of these advertisements.

Dr. H. E. Magee of the Ministry of Health said that the war had tested nutrition theories and that they had come

(Continued on page 184)

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## Professor J. D. Bernal, F.R.S.

If the B.B.C. ever sponsors a Brains Trust with the object of providing knowledge rather than entertainment the choice of Prof. J. D. Bernal for resident membership should be automatic and inevitable. An omniscient scientist, he is affectionately known as "Sage", the nickname which is said to have been given him by fellow students while he was yet a schoolboy and which has stuck to him ever since. Bernal is not one of those who believe that specialisation must result in knowing more and more about less and less. His own interests range over many branches of science. He is also something of a connoisseur of painting, and his knowledge of architecture is such that he can usually tell you the age of a building with an accuracy of  $\pm$  ten years after taking a quick look at it. He is well informed about history in general, and not merely the history of science. Lean, soft-spoken, with a mass of very fair hair, generally wearing a tie which follows no scientific law, he is one of the most discussed personalities of contemporary science. By the standards of Fleet Street, as well as those of Burlington House, Bernal is *news*, and he is better known to the general public than most scientists. Laboratories are not sufficiently romantic places to attract many novelists, but it is no secret that one of the rare novels written about scientists contains a character identifiable (wrongly perhaps) with Bernal.

Professor John Desmond Bernal hails from Ireland; the son of a farmer, he was born at Nenagh, Tipperary, on May 10, 1901. There are many apocryphal stories about him, one of which purports to show how early his scientific curiosity developed. About the age of seven, having read or been told about the new rays which could penetrate solid materials, he took it into his head to produce some X-rays at home. The tale runs that he collected a large number of candles, which he set up on the top of a

table. Using the opened pages of a screen of books behind the candles as a reflector, he held his hands in front of his face and peered at his fingers in the hope of being able to see through them. Whether he succeeded is not told, for the experiment apparently came to a sudden and disastrous end; the candles got out of hand, and the boy who was later to become a leading authority on X-ray analysis had to be punished for the conflagration which followed!

Bernal first went to the Roman Catholic public school of Stonyhurst, but was later transferred to Bedford School. Does the fact that he attended two public schools explain the forcefulness with which he voices his condemnation of the public school system? After taking his degree as an undergraduate of Emmanuel College, Cambridge, he became a research assistant at the Davy-Faraday Laboratory of the Royal Institution, where he worked under the late Sir William Bragg, who was then perfecting the technique of X-ray analysis for the investigation of atomic structure. In 1927 he returned to Cambridge as lecturer on structural crystallography. Bernal has done some remarkable work with X-rays, and using the technique of crystal analysis he has probed the structure of such complex substances as vitamins, hormones and proteins. On one occasion a bright but erroneous idea about the constitution of a particular plant virus (some viruses are crystalline and are therefore amenable to X-ray analysis) was corrected by Bernal after only a few hours' study with X-rays. By 1934 he had become assistant director of crystallographic research under Lord Rutherford. It is interesting to note that Bernal has been associated with two brilliant scientists who were both farmers' sons like himself—Lord Rutherford and Sir William Bragg.

X-ray analysis is, of course, of great importance in structural chemistry. Here is Bernal's view on the subject. "In the metrical structural chemistry of the future it will

take its place with the study of spectra and magnetic properties of molecules. Already systematic inorganic chemistry . . . needs to be rewritten round the data supplied by crystal analysis." Pure chemists have long realised how essential these studies are, and to-day it is not unusual to hear industrial chemists saying that X-ray methods of identifying and determining the state of combination of the various elements may displace the conventional methods of chemical analysis.

1937 saw Bernal elected an F.R.S. At the time he was only 35, so that he was then the youngest fellow of the Royal Society. The following year he was appointed university professor of physics at Birkbeck College, London, where his contentious mind must have had plenty of exercise in his frequent meetings with Dr. Joad in the common room!

Bernal's nature has been neatly described by a fellow scientist: "His mind darts about amid a stupendous mass of learning and usually keeps pace with his equally agile tongue; his hands have performed several remarkable experiments, but are quite unable to keep up with his ideas." Bernal is a great deal more than a brilliant research worker. He is keenly interested not only in the internal politics governing the world of science, but also in the results which arise from applying—or not applying—scientific knowledge and methods to modern industry and society. There is nothing superficial about his studies in this field. Readers may be interested to know that for ten years he has been compiling facts about the history of science for a book which is bound to be a best seller—if, being a very busy man, he can ever find time to get it to the printers! *The Social Function of Science* gives us a preview of this larger unfinished work; for it provides not only a vivid expression of his own individual creed as a scientist and as a citizen, but also constitutes a valuable reference book. Indeed *Social Function* is quoted more widely than any other single scientific book. It has given Bernal many followers and not a few imitators; and readers have probably suffered the person who gives his views about science without disclosing that these are taken straight

from Bernal! The book shows him as a vigorous constructive critic, pointing out the weak links in the development and organisation of science in this country with devastating clearness, but also putting forward valuable suggestions to make good existing deficiencies. To implement only those proposals contained in the appendix of *Social Function* and in the Bernal Report (*Scientific Worker*, 1938, 10, 4) would take a great number of years. We may expect to see many of these ideas adopted in the future, but by the time they are eventually accepted as being both practicable and essential their origin will probably have been forgotten in that haze of compromise which, in Britain, is usually associated with every progressive step we take. In the realm of ideas credit is not booked as carefully as in the banking world, but this point should not disturb a man of Bernal's social conscience.

It need hardly be stated that Bernal is a Marxist. Before the war his strong pacifist and anti-Fascist views were well known. We find him, in the 1930's, a member of the Cambridge Scientists' Anti-War Group, a group which coupled its attack on warmongers with many useful suggestions as to how Civil Defence could be improved. (It is worth noting that it was this band of scientists which pointed out that poison gases in the form of smoke could penetrate the ordinary civilian respirator; it was not until 1940, at Dunkirk time, that the Government rectified this defect in our gas equipment!) With the outbreak of war Bernal was able to throw his talents and ability unreservedly into the fight against Fascism. For the Ministry of Home Security he has investigated the way in which bombs burst. A good account, though not complete for obvious reasons, of this work was given in his lecture to the Royal Institution in 1941. Now I understand he is even closer to the front line, being Lord Mountbatten's personal scientific adviser at Combined Operations. His political convictions being what they are, he must get a great kick out of being with a command which has as its motto "United we conquer"!

WILLIAM E. DICK.

## How Many Fungi?

FUNGI, if not the most conspicuous, are among the most numerous of organisms. One gram of soil may contain 100,000 fungus spores, in addition to several million bacteria. They play an important part in the economy of nature by decomposing organic residues. Some are used as food, and one species—ergot—is a useful drug. Others cause disease in man, animals, and especially plants, or damage a variety of stored products. A number, on the other hand, have important industrial uses.

How many fungi there are is a matter for speculation. One compilation, Saccardo's *Sylloge Fungorum omnium hucusque cognitorum* (to give it its full title) gives short accounts in Latin of all the species of fungi that have been described, and the 25 volumes contain about 80,000 numbered specific entries. It would, if brought up to date, contain approximately 100,000. There is, however, a tendency among systematists to regard their discoveries

as unique. Competent authorities now recognise only half of the 7,000 genera of fungi that have been proposed, and it has recently been suggested that possibly only a third of the named species have an objective existence.

The distribution of the average fungus is wider than that of the average flowering plant, and a number of individual ubiquitous fungi have been described more than a hundred times under different names. This, combined with the fact that many fungi exist in two or more states which are not infrequently given different names, and mycologists' ignorance of each other's work, has led to a great multiplication of names. On the other hand, large areas of the world are as yet unexamined mycologically, and there are undoubtedly many new species awaiting discovery. Perhaps only a third of the total number of fungus species are known, that is to say there are 100,000 species of fungi represented on the earth.

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# Coal: its place in the National Economy

E. W. SALT, M.P.

*Chairman, Parliamentary and Scientific Committee*

THAT we must plan now for our post-war prosperity is, perhaps, in danger of becoming a commonplace, and the immensity of the problem, its correct proportions and its balance are therefore apt to be lost sight of in a babble of talk. And yet, on what we do now depends the life of our country for generations. How can a strong Britain be built in the new world? What should be the centre of gravity, the first point of application of our efforts in this stupendous task? To any serious observer, it is surely at once evident that one pillar of the edifice must be the use of coal.

The first great need of this country after the war will be export markets. Domestic reforms, however urgent, must be paid for, and with the loss of our foreign investments, exports are almost the sole source of cash in hand. Now the one great natural asset of this island is its rich coal measures. In 1913, at the then ruling prices, we exported coal to the value of £50,727,000, while we imported liquid fuel to the value of £10,856,000. In 1938, however, this balance had altered catastrophically; our coal exports had fallen to £37,406,000 while our imports of liquid fuels had risen to £40,718,000.

Apart from its unique value in our foreign market, coal is the chief raw material of our home industry. Practically all our industrial power is derived from it; our railways and tramp shipping depend on it; our very homes are warmed by it.

Bearing in mind that the coal industry is the pivot on which our national economy turns, the Parliamentary and Scientific Committee has recently been considering the likelihood of the British coal industry's regaining the position which it had, long before the outbreak of this war, undoubtedly lost in world trade. The Committee consulted, in addition to experts of the Ministry of Fuel and Power, specialists on coal utilisation research, and from its deliberations several striking points emerged.

First of all, coal is a wasting asset, and the fact must be frankly faced that some of our finest coal measures are practically exhausted, that year by year our coal is poorer and more difficult to mine. The obvious answer to this is that we must first of all improve methods of mining, and secondly, learn to burn more efficiently and economically coal, of whatever quality, when it has been raised to the surface. To do this, research on a scale commensurate with the magnitude of the problem must be undertaken without delay.

At present, out of a total of 170,000 qualified technicians (scientists and engineers) included in the records of the Central Register, only a few hundreds are employed, either in the Coal Industry, in Government Departments or at Universities, in coal research.

The Committee reviewed in brief the work, by no means negligible, which has already taken place in coal utilisation research. For example, the coal required to produce a unit of electricity has been halved within a generation, and

similar advances have been achieved in several other fields. Taking a general view, it has been estimated that, whereas in 1913 only 15% of the potential energy in coal was turned to useful account, and the remaining 85% wasted, by 1938 the useful recovery of energy had reached 30%. A certain proportion of the 70% is undoubtedly wasted by carelessness on the part of industrial operatives, and the Fuel Efficiency Campaign undertaken by the Ministry of Fuel and Power should considerably reduce this wastage. There is, however, still room for great improvement, and the Committee felt that, to effect such improvement, it would not do to rely solely upon methods which have proved efficacious in the past.

In a climate the vagaries of which are a byword, it is only natural that a large proportion (in fact, in Great Britain, roughly one-third) of the coal raised should be used directly or indirectly for the purpose of climate control. It is essential that appliances for the consumption of this vast quantity of coal should be as economical as is consistent with the highest degree of efficiency. This applies as much to electrical and gas installations as to solid fuel fires, and a spirit of co-operation between the three industries would be of inestimable value in this connection. Moreover, it is of the utmost importance that even raw bituminous coal should, both in industrial and in domestic appliances, be burned smokelessly.

Further points brought before the Committee as requiring immediate attention were the use of coal for road transport in the post-war period, when liquid fuels will be scarce and expensive; the various methods of coal processing, such as low temperature carbonisation; the cleaning and sizing of coal; the utilising of low grade coals; the preservation for posterity of some portion of our higher grade coals; the development for export of efficient coal-using machinery, and, finally—possibly most important and certainly most spectacular—the investigation of coal as a source of carbon compounds, providing raw materials for chemicals, plastics, synthetic rubber, soaps, lubricants, and especially liquid fuels for aviation. Some of these investigations are proceeding actively, notably in the laboratories of the British Coal Utilisation Research Association, but, in the opinion of the Committee, not on anything like a sufficient scale.

## Committee's Recommendation

The Committee contrasted the total, certainly less than £600,000, spent annually in Great Britain on coal utilisation research, with the figure of £6,000,000 spent in research in 1938 by the American Petroleum Industry. By the application of scientific research on an unprecedented scale, the treatment of crude oil has been completely transformed in the past twenty years. It was in the firm belief that as much, and more, could be done for the British coal industry by equally bold and comprehensive researches

that the Committee put forward its recommendations. These, briefly summarised, are:

1. *National Coal Survey.* The main responsibility to be undertaken directly by the Government is the rapid completion of a survey of our actual and potential sources of carbon compounds, including coal, petroleum, lignite, peat, wood and charcoal, through the machinery of the present National Coal Survey. The Coal Survey itself should, in future, include qualitative, as well as quantitative, estimates of each class of coal.

2. *Industrial Coal Research.* To raise the proportion of coal research workers to a level commensurate with the total number of workers in the industry, coal research should employ several thousand scientists, engineers, and other technicians. Of these, more than half would be assigned to the fundamental task of producing liquid fuels and chemicals from coal. The remainder would undertake the development of improved methods of releasing and utilising the energy in coal. Actual programmes proposed include the building of a coal-fired ship, with all the refinements of modern engineering; the construction of pulverised fuel locomotives, of steam wagons, of producer gas lorries and of methane cars; the trying out of large and small boilers and of experimental furnaces, embodying new principles of combustion and heat transfer; the erection of a complete power station, supplying electricity, but devoted exclusively to research into electrical generation. The potentialities of gas grids should also be fully investigated in actual practice, and many other outstanding problems of the gas industry are of such a kind as to require exploratory plants on a large scale.

On the domestic side, problems of immediate urgency include the further development of the smoke-reducing fire, continuous-burning coal cookers, improved gas and electric cookers and the supply of hot water to all houses and flats. There must be demonstration and test houses, built in collaboration with local authorities and private builders and—of paramount importance—the increased efficiency envisaged in the domestic use of coal must not involve any increase in fuel costs. The coal, gas and electrical industries are already inquiring into how they can meet the requirements of the Heating and Ventilating Committee of the Ministry of Works under Professor Sir Alfred Egerton, the report of which is to be issued shortly.

3. *Cost of Proposed Research Programme.* So extensive and urgent a programme of research will cost a great deal of money. The employment of a thousand scientists and engineers means an annual expenditure of at least £1,000,000. This is equivalent to about a penny per ton on the coal raised in a year, and it may ultimately be necessary to employ several thousand workers. The total cost to the country of energy (steam, gas and electricity), chemicals, fertilisers, etc., is at least £750,000,000 per annum. On this basis, the proposed research expenditure represents a minute percentage of the sums involved.

In assessing the value of research, the Committee emphasise one fact which is often overlooked, namely, that the results of the research are cumulative. If the present efficiency of coal utilisation, i.e. 30%, can be improved at the rate of 1% per annum, it will reach a level of 45% in fifteen years, by which time the saving would amount to £100,000,000 a year. Adding the value of new industries, perhaps as important as rayon and plastics, which may reasonably be expected to develop as a result of this work, the figure might well be doubled, giving an increase in our national income of some £200,000,000, which represents a forty-fold return on research expenditure. Since the whole nation will benefit by the results of coal utilisation research, the work should be generously subsidised by the Government. It should, however, be carried out by the coal and other branches of the fuel and power industries themselves, with a minimum of bureaucratic control, since this would ensure that the results of research are effectively and rapidly applied in practice. It will, of course, be essential to secure the interest of the Universities, and grants should be made, through the central industrial research organisations, to encourage fundamental research in fields which affect the study of coal. Research programmes must be properly co-ordinated, and there must be no overlapping. In this connection, the Committee draws attention to the new Standing Consultative Conference, under Sir Harold Hartley, lately set up by the Department of Scientific and Industrial Research, which has as its most important function the co-ordination of research.

4. *Demobilisation of Technicians.* It is urged that preparations should begin immediately to ensure that a sufficient proportion of the chemists, physicians and engineers now employed by the Service Departments should be guided into coal research in preference to other lines of investigation less vital to the nation. It must be remembered that the problems outlined above will not wait for a long period of planning after the cessation of hostilities. It is essential that, immediately peace is declared, active work should go into full operation.

5. *Plans for Expansion.* It will take some time to build up a complete organisation which would justify expenditure on the scale foreshadowed above, but the coal, gas and electrical industries should at once be called upon to submit proposals for the rapid expansion of all the various research organisations.

\* \* \*

It will be seen from the foregoing that the Parliamentary and Scientific Committee has taken its responsibilities in this matter very seriously indeed. It has put out bold, constructive and well-considered proposals. It considers coal research to be of paramount importance to us in this country, at this epoch—to be, in fact, an investment which will literally repay us a hundredfold.

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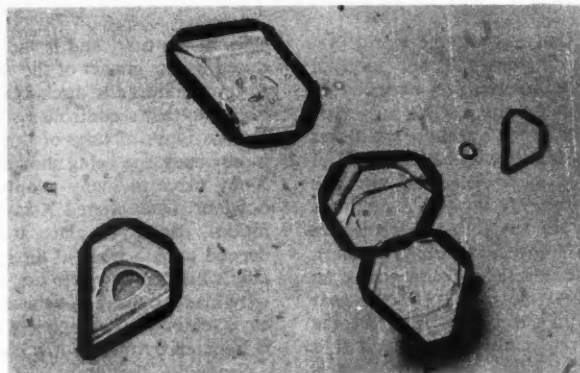


FIG. 1.—Alum crystals

## X-Rays and Atoms

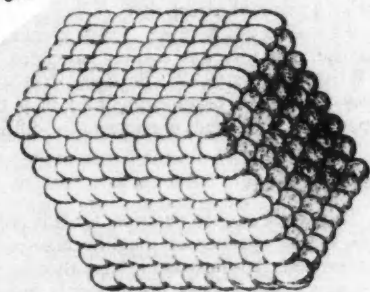
H. LIPSON, M.A., D.Sc., F.Inst.P.

If one dissolves a chemical compound, such as alum, in water and then allows the solution to stand, crystals are deposited. Looked at without imagination, the formation is quite ordinary: the water evaporates and the solid does not; therefore, since there is a limit to the amount of solid that can stay dissolved in the liquid the extra solid must come out of solution. Yet crystals must be reckoned amongst the most remarkable things that Nature produces.

Fig. 1 shows some alum crystals that have been formed in the way described above. Observe their remarkably straight edges and contrast them with the irregularities usually found in Nature. Nature dislikes straightness. Look at a map and observe how all the straight lines on it are man-made—the roads, the railways, the canals; Nature, if left to herself, produces the irregularities of rivers, coastlines and mountains.

Why then are crystals so perfectly formed, since their growth is quite natural? Why are their faces so flat and their edges so straight? These questions have provided food for thought for centuries. There can be only one answer, that there is an underlying regularity of some sort.

FIG. 2.—The structure of calcite as envisaged by Huygens.



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About two hundred and fifty years ago Huygens stated this opinion definitely, although there must have been many who had reached similar conclusions before him. He envisaged a calcite crystal as composed of large numbers of egg-shaped particles stacked together as shown in Fig. 2. It can be easily seen that if the stacking is perfect plane edges and straight edges must result.

Such a way of building a crystal could explain other properties—cleavage, for instance. Some crystals, if given a sharp blow in a given direction, break with a beautifully plane fracture. Rocksalt breaks into cubes, for instance, and anyone who has handled mica knows how easily it cleaves into thin sheets. Suppose that the egg-shaped particles stick together less well at their ends. Obviously planes containing such junctions will be planes of weakness and so the crystals will tend to break across them. Because the theory accounted so clearly for crystal properties such as these and could even account for relations between the angles that the faces make with each other, it was generally accepted as correct in the scientific world.

So far, so good. But what are the crystal units? The approach to the answer to this question had to wait until the birth of the atomic theory. In order to explain the laws of chemistry, scientists had been forced to the conclusion that matter was made up of particles. These particles—atoms—could combine together to form all the

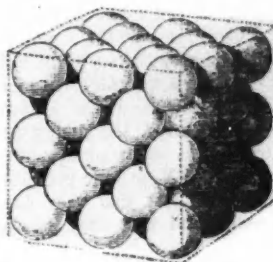


FIG. 3.—One of the ways suggested by Barlow for arranging equal spheres in space.

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infinite variety of materials that exist in the world; yet there are only about ninety different ones and most of them occur but rarely. The atoms retain their individuality whatever processes they go through, but the properties of a particular piece of matter depend on how the atoms in it are joined together. The matter may be composed of groups of small numbers of atoms—molecules—and this was at first supposed to be the way that all matter was formed. Suppose that the molecules arranged themselves neatly next to each other. Then we should have crystals.

This was all very plausible and, as we now know, in some cases remarkably near to the truth. But the next question was a much more difficult one: "How are the atoms arranged in crystals?" It might be thought that there is a possibility of answering this question by magnifying the crystal with a super high-power microscope so that the atoms in it could be seen. This is a vain hope; light is far too coarse for us to see atoms by it. A simple analogy will make this clearer. You have a coin in your pocket; is it a penny or a half-crown? You cannot be quite sure by merely running your finger round the edge, but with your finger-nail you can tell with certainty whether the edge is milled or not. The finger-nail, which is sharp, can detect the milling; the finger, which is blunt, cannot. In a similar way light is too coarse for us to see atoms by it. When this fact was discovered it seemed that a limit was reached for the smallest detail that it would be possible to detect, for light was then the finest tool known.

So man was left with nothing but his imagination. This is not a weapon to be despised. Barlow, in 1897, suggested many ways of arranging atoms and these are now known actually to exist; one of them, reproduced in Fig. 3, is an exact representation of the arrangement of atoms in many metals and alloys. Still, more than imagination is needed to place a theory on a sound footing, and the experimental basis was found quite suddenly, in the beautiful discovery of the diffraction of X-rays by crystals.

## X-Rays

The discovery of X-rays by Röntgen in 1895 was the most important development of the experiments on electrical discharges in gases—the experiments that upset the nineteenth-century belief that all the fundamentals of physics were known and that all that remained was to dot the i's and cross the t's of the subject. The apparatus used in these experiments was not elaborate: a glass tube from which the air can be gradually pumped out and a supply of high-voltage electricity are all that is necessary. When the air in the tube is at the same pressure as that of the air in the room no current passes because the air is too good an insulator. As the air is pumped out a current starts to pass and increases as the pressure falls; at the same time the tube is filled with a soft violet glow. As still more air is pumped out the current again finds difficulty in passing and the colours in the discharge tube begin to fade. Ultimately, if all the air were removed, the tube would form an even better insulator than it was originally. It is just before this stage is reached that X-rays are produced. Röntgen discovered them by the fact that they cause certain substances to fluoresce and that they blacken photographic plates.

Close examination showed that the rays came from the

sides of the tube, and it was realized that they were produced by the impact of the discharge. It was logical then to try to direct the discharge on to a specially interposed object so that a controlled source of X-rays would result; various types of tube of this sort were designed, a commonly-used one being shown in Fig. 4. This still typifies X-ray tubes to many people. Improvements in design, however, have altered X-ray tubes almost out of recognition. In the first place, it is not satisfactory to have to depend upon a trace of air in the tube; the pressure may alter while the tube is in use, and many ingenious attempts were made to overcome this difficulty. Now, however, the air is removed as completely as possible and the discharge is initiated by means of a hot filament.

Secondly, the energy of the discharge is converted almost entirely into heat at the target surface where the X-rays are produced. The amount of energy that one could get into the tube was therefore limited. Attempts were made to put this limit as high as possible by making the target of tungsten, which has a high-melting point, and running the tube with the target white hot. A more efficient and satisfactory method is to direct a jet of water at the back of the target. Even with this method, the one now commonly used, there is still a limit to the intensity of the X-rays that can be produced, and the physicist, with his usual "divine discontent" is aspiring to still greater heights by moving the target about so that the heat is not generated at the same place all the time.

Thirdly, a great deal of attention is now given to the material of the target, and we can tell accurately what will be the properties of X-rays given out from different metals. Copper is often used as a target because it is a good conductor of heat, but other metals may be soldered on to it or plated electrically.

With these improvements, and a host of others designed to make the X-rays more accessible to the work they are to do, the present-day tube looks nothing like its ancestors. Two examples are shown in Figs. 5 and 6. The former is complete in itself; it has merely to be connected to specified supplies of electricity and water. The latter is more of an experimental type and has to be pumped out each time it is used. Different targets may be inserted, and burnt-out filaments may be replaced.

With all this outward show of change, however, the fundamental process of producing X-rays has not altered: a stream of electrons, which form the discharge, must be produced in a highly evacuated vessel and caused to strike a material object.

What then are X-rays? Forty years ago it would have seemed that this was entirely unrelated to the question "What are crystals?" So it is. Yet we shall see how they have both become involved in a third, and again apparently unrelated, phenomenon—diffraction.

## Diffraction

This is not easy to describe, for it is not associated with any of the experiences that the man-in-the-street meets. Experiments to illustrate it have therefore to be expressly designed, and a brief discussion is necessary about the conditions under which it may be observed.

It is usually said that light travels in straight lines, and ordinary experience tells us that this is so to a high degree



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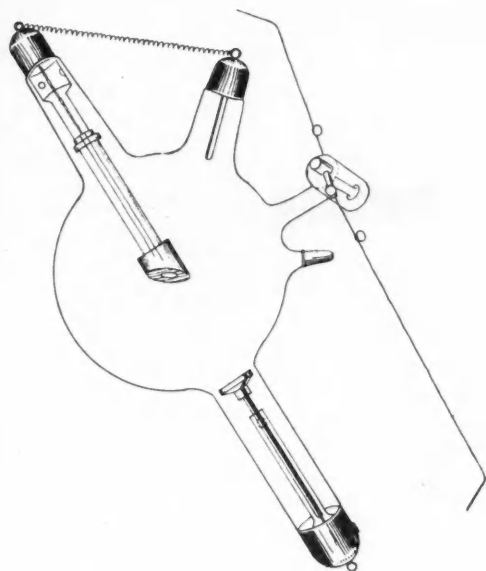


FIG. 4.—An early form of X-ray tube.

of accuracy. Nevertheless it is not perfectly true, and if, for example, we study the light passing through a very small hole we find that it spreads out more than it should do if light travelled accurately in straight lines. This is the phenomenon of diffraction. The spread is not great, and precise conditions are necessary in order to observe it; but there is one way in which quite large angular deviations of a beam of light may be produced by diffraction. This is diffraction by a grating.

To observe this sort of diffraction three conditions are necessary: first, we must have a wave-motion travelling in a definite direction; secondly, we must allow this wave-motion to fall on an object that has a structure that repeats regularly; thirdly we must have a means of detecting all possible wave-motions coming from the object.

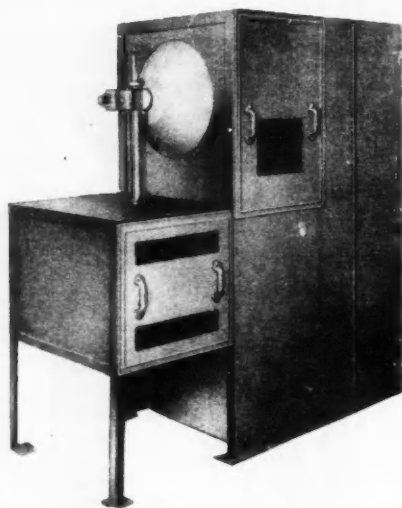
Wave-motion is a fairly simple notion to grasp. The most obvious case is provided by the ripples on the surface of water. The ripples move along the surface, but the water is not carried along with them; a point on the surface merely moves up and down, as is easily seen if an object such as a cork is allowed to float in the path of the ripples. Sound is a less obvious wave-motion. It is carried by waves of pressure in the air, but the air does not move with the sound. Neither water ripples nor sound waves are convenient for demonstrating diffraction by gratings, in the former case because it is difficult to produce ripples going only in one direction, and in the latter, because sound does not lend itself to accurate observation of direction. But there is another sort of wave-motion that has neither of these disadvantages, namely, light.

The difficulty of visualizing light as a wave-motion is



Courtesy of Philips Lamps, Ltd.

FIG. 5.—A present-day X-ray tube.



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FIG. 6.—A demountable X-ray tube.

due to the extreme smallness of its wave-length; this is about one-two-thousandth of a millimetre, in contrast to the wave-length—the distance between two crests—of water ripples, which may be of the order of several centimetres. To diffract light we need a regularly repeating pattern on a fine scale. Such a thing does not occur naturally, so we must use something man-made. A handkerchief, for instance, contains sets of fibres running parallel to one another in two perpendicular directions. Hold a handkerchief as close as possible to the eye and look through it at a small source of light. In days of peace a distant street lamp would have been ideal, but a small hole in front of an indoor lamp will do; some fancy lamp shades are held together by cords passing through holes and light coming directly from the filament through one of these holes will be quite convenient. Without the handkerchief we see one point of light; with the handkerchief we see a regular pattern of points, stronger in the middle and fading towards the edges. This is diffraction.

It might be thought that the separate points of light are due to separate holes between the threads of the handkerchief. That this is not so may be proved by the fact that the pattern does not move if the handkerchief is moved so that it is always parallel to itself. Another simple experiment is as follows. Keeping the handkerchief close to the eye, stretch it crosswise. The threads will separate further in the direction of stretching and will come closer together in the perpendicular direction. But it will be seen that the diffraction pattern does the opposite of this; the spots become *closer* in the direction of stretching. From this it may be appreciated that the effect is not a simple one and the full theory is too complicated to be described here. All that has been attempted is to show that the effect does exist and these simple experiments show this quite well.

For accurate work a much finer and more perfect structure than that of a handkerchief is required. In fact we need a regularity that is nearly as fine as the wavelength

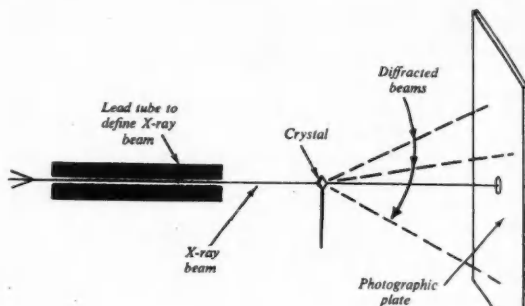


FIG. 7.—Experimental set-up for Laue photographs.

of light. This has been successfully achieved by ruling lines on glass or metal. It has been found possible to rule about six thousand lines on each centimetre, and since these lines must all be similar it is necessary to do the ruling with a diamond point—the hardest substance known—so that it will not wear away. The result is called a diffraction grating. The lines cannot, of course, be seen with the naked eye; the surface on which they are ruled merely appears to be delicately coloured and the colours change as the grating is turned. One of the few corresponding natural phenomena is produced by mother-of-pearl; the colours on this are caused by the fine striations with which the surface is covered.

The comparison with crystals should now be obvious. If crystals have an internal regularity, should they not also act as gratings and diffract light? No, for again light is too coarse; in fact the problem is exactly the same as that of seeing atoms with a microscope. The wave-length of light is small—about one two-thousandth of a millimetre—but atoms are smaller still—about one ten-millionth of a millimetre. If we wish to use crystals as diffraction gratings we must have a much finer wave-motion.

This was the idea that Laue had in 1912. It was being suggested that X-rays were just such a wave-motion but otherwise of the same nature as light. Would they therefore be diffracted by crystals? The experiment was tried. A narrow beam of rays was projected on to a crystal of copper sulphate and a photographic plate was set to catch the diffracted beams as shown in Fig. 7. (Of course, it was not so simple as that; original experiments never are; it is only later on that all the experimental details seem so simple and obvious.) On developing the plate, spots were found around the blackening due to the direct beam. The diffraction of X-rays was an experimental fact. The first X-ray diffraction is shown in Fig. 8.

Two birds were killed with one stone: X-rays were established as a wave-motion and a tool was found for examining the structure of matter.

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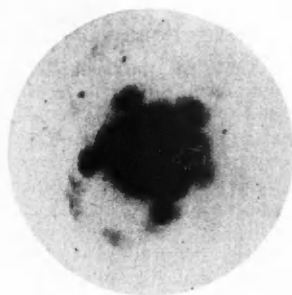
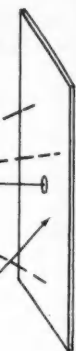


FIG. 8.—The first Laue photograph.

Both figures reproduced from W. L. Bragg's "The Crystalline State," by kind permission of the author and publishers, G. Bell & Sons, Ltd.

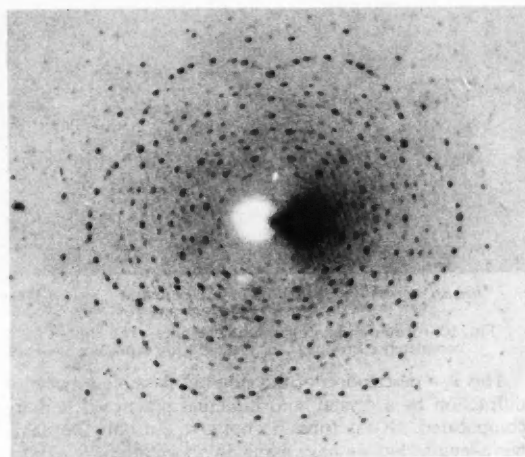


FIG. 9.—Laue photograph of Beryl.

## The Diffraction of X-rays

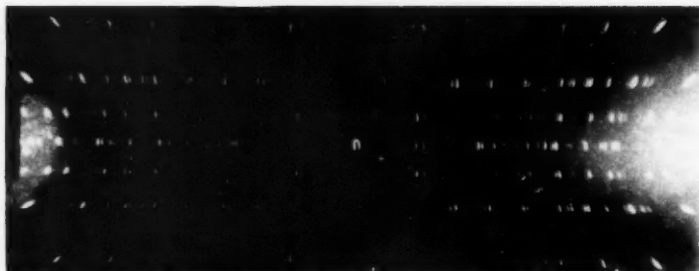
Since the wave-lengths of X-rays are about a thousand times smaller than those of visible light the two radiations behave quite differently in most respects. Nevertheless, their properties are essentially the same, and all the characteristics of light can, with sufficient attention to detail, be found in X-rays. One of the most obvious characteristics of visible light is colour. Colour is dependent on wave-length, red light being of a longer wave-length than blue, for instance. White light is a mixture of many different wave-lengths. X-rays can also be produced with different wave-lengths and the correspondence with visible light is so close that a mixture of such wave-lengths is usually referred to as "white" X-rays. Such a mixture is the predominant part of the radiation emitted from X-ray tubes, especially if a target of a heavy metal such as tungsten or gold is used. Some of the radiation is also concentrated into definite wave-lengths which are characteristic of the target material, especially if lighter elements, such as copper or iron, are used as targets. These are called "characteristic" X-rays and they are used for most present-day research. These characteristic rays have three different wave-lengths, called "K-beta" and "K-alpha", the latter being double.

When the photograph shown in Fig. 8 was taken all these details about X-rays were unknown, nor was anything known about crystal structures. The interpretation of X-ray photographs was therefore doubly difficult, and in the absence of a solution to one of the problems a solution to the other could not be obtained. A way out of the impasse was opened up by the ideas of W. L. Bragg; he suggested a simple physical way of considering diffraction by a crystal and this led directly to a disentangling of the problems of the structure of X-rays and the structure of crystals. The former is by far the simpler, and it is not too much to say that finality has now been reached on all the major points in it. The study of crystal struc-

tures, on the other hand, is far more difficult and although many have been successfully determined, general methods of solution are still in their infancy.

The process of diffraction by a crystal is not easily described, even by analogy with the diffraction of light by a plane grating. To illustrate this, let us do some more experiments with the handkerchief. We have already seen that the diffraction pattern remains constant when the handkerchief is moved parallel to itself. Now rotate it in its own plane; the pattern rotates in the same way. Finally, rotate it out of its plane; the pattern elongates in a direction at right angles to the axis of rotation provided it is not rotated so much that the light is completely cut off. These effects are typical of diffraction by plane gratings; the essential point is that the changes are always gradual. With a crystal, however, quite different effects would occur, merely because a crystal is regular in three dimensions, not in two. Suppose that the crystal is illuminated by one of the characteristic wave-lengths. Then we should find fewer spots than are given by a plane grating, although the structure of the crystal is by far the more complicated. Moreover they would probably be irregularly arranged. Why is this? The answer would be given by rotating the crystal; the original spots would disappear to be replaced by others in different positions, and these in their turn would also disappear. Thus the process would go on, the diffraction pattern twinkling in and out in a most interesting manner. The total number of spots would be large, as we expected.

These effects take place because, with a three-dimensional grating such as a crystal, a diffraction spot will not occur unless the grating is in the correct position to produce it. It is unlikely that a stationary crystal will be in the correct orientation to produce more than a few diffraction spots and so only a few are observed. As the crystal is rotated it passes through many different diffracting positions and spots will flash out of it passes through each one.



Reproduced from W. L. Bragg's "The Crystalline State," by kind permission of the author and Dr. Bannister and the publishers, G. Bell & Son, Ltd.

FIG. 10.—Rotation photograph of Braggite. The film, in the form of a cylinder, completely surrounds the crystal during exposure, and is here shown flat.

This is a description of the simplest possible process of diffraction by a crystal, and in actual practice it is more complicated. X-ray tubes do not give out only the single wave-length that we have assumed above; they give out a great deal of white radiation as well. How will this affect the observations? The orientation that the crystal must have to produce a given diffraction spot is governed by the wave-length, so that even if the crystal is stationary it can choose which wave-lengths to diffract and so will produce a pattern. Such a pattern is called a "Laue pattern", and it will be realized that the photograph shown in Fig. 8 is of this sort. A more striking Laue photograph is shown in Fig. 9. If this pattern could be made with visible light it would be still more striking for the spots are formed from different wave-lengths and so would be differently coloured.

Little use is now made of Laue photographs. It is preferable to rotate the crystal or to oscillate it through a small angle; one then gets a much more orderly sequence of spots as is seen on the rotation photograph shown in Fig. 10. Here the spots are all formed by K-alpha radiation, the beta radiation having been eliminated by a screen and the white radiation being spread over the background of the photograph. The dual nature of the alpha radiation is shown by the doubling of the spots at the right- and left-hand sides of the film.

Both the Laue and the rotating crystal methods require single crystals. Although it is surprising how small a crystal it is possible to use, sometimes only a confused mass can be obtained. This is particularly so for metals. To provide for this contingency, the "powder" method was devised. If the specimen contains crystals of all possible orientations there will always be some that will produce any one diffraction spot. Corresponding diffraction spots from different crystals will lie on curves, and parts of these curves can be seen in the powder photographs of metals shown in Fig. 11. These photographs are simple because the structures that produce them are simple; the structure that gave the rotation photograph

shown in Fig. 10 would give a most complicated powder photograph, each line being formed by a curve passing through each spot on the film.

### Investigation of Crystal Structures

These are the methods by which the diffraction pattern is recorded; we have now to see how it can be used. This is not easily described. Methods for determining crystal structures are indirect; we have to think of a structure and then, by calculation, find out what diffraction pattern it will give. If this agrees with the observed pattern the problem is solved; but this is rarely the case at the first attempt and the process has usually to be repeated several times before success is achieved. Solving a crystal structure is like no other process in physics; it resembles rather the solving of a chess problem. The diffraction spots are the chessmen and each one means nothing in itself; what one has to find is the idea underlying the pattern of the men, and how each one separately is affected by this idea.

In devising structures to try we do not have to work entirely in the dark. To begin with, from the dimensions of the diffraction pattern we can find the size and shape of the crystal units—the Huygens' "egg" (Fig. 1). Thence we can deduce how many atoms are contained in this unit. The crystal itself may provide information about the symmetry of the atomic arrangement, and in some rare cases—many metals, for instance—this is sufficient to give all the atomic positions. Normally, however, this information will not take us very far and we must proceed to use less direct evidence; no possible source of information must be neglected. For instance, we know the amount of room that certain atoms take up in other crystals and so we must allow them the same amount of room in the one we are studying. The crystal that gave the Laue photograph shown in Fig. 9 was completely solved in this way, but again this very rare. Many atomic arrangements are usually possible—too many for each to be tried separately—and any evidence, chemical or physical, that will help to eliminate certain possibilities must be considered.

Attempts are being made to produce methods for solving structures directly, by combining the information from the diffraction pattern to form an image of the atomic arrangement. There is no doubt that in the future such methods will be increasingly used, but meanwhile one has to depend on the older methods. These involve sheer hard work, with days or even weeks of analysis and calculation; errors of judgment and disappointments are inevitable; but the final thrill of finding the correct structure, and seeing the calculations, one by one, fit in with the experimental data, makes all this well worth while.

FIG. 11.—Powder photographs of metals. The film is also in the form of a cylinder during exposure, as in Fig. 10, but only half of the complete photograph is shown here. (a) aluminium; (b) zinc; (c) molybdenum.



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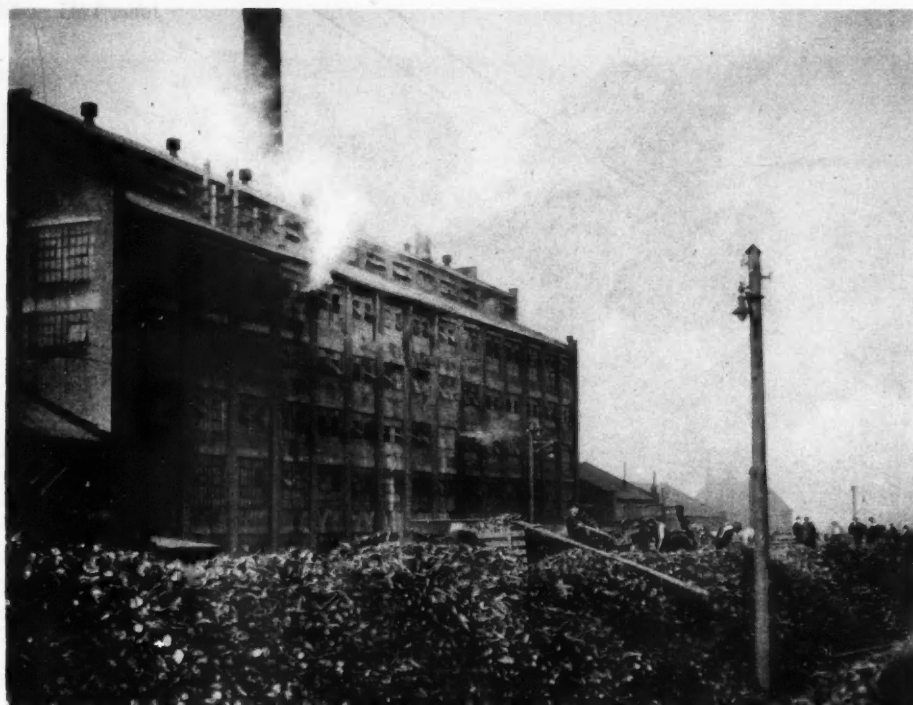


FIG. 1.—An English Sugar Beet Factory—unloading sugar beet into the silos. A factory of this capacity deals with 2000 tons of beet every 24 hours.

## From Beet to Sugar

W. H. PARKER, M.Sc., and H. WICKENDEN

Foods may be roughly classified into flesh-formers or body builders and energy producers. The bulk of the foods consumed by man are of the latter class which includes *inter alia* "sugar". The energy required for the proper functioning of the body is supplied by the oxidation of the food consumed, a process which is always accompanied by the generation of heat. The calorie is the unit of heat generally employed to measure the energy producing value of a food.

Granulated sugar is easily one of the cheapest energy producing foods in terms of calories; it is also the easiest assimilated of any of the ordinary foods consumed by human beings. The Royal Society (War) Committee estimated that before the Great War 1914-18 white sugar accounted for 12% of the energy value of the total food supply of the United Kingdom. Before that date however, some four-fifths of this country's sugar imports came from the Continent of Europe in the form of beet sugar; the remainder was imported cane sugar. People did not know whether they were using beet or cane sugar and did not trouble to enquire; nor did it matter, because the two are absolutely identical.

Since we have had a home-grown sugar industry, there seems to exist in some minds a notion that sugar from beet is not so sweet as cane sugar, or in other ways it is an

inferior product, particularly as regards its preserving quality for jam making. This is quite an erroneous conception. On the Continent beet sugar has been used almost exclusively for a hundred years or more, and those who have travelled abroad in pre-war days can testify that sweets and confections there were the equal of anything we produced. Experiments conducted under the auspices of the Ministry of Agriculture and Fisheries at the University of Bristol Research Station, Chipping Campden, in 1930, and confirmed many times since by others, have demonstrated the complete suitability of beet sugar for the making of jam, jellies and other preserves and further, to quote from the report, "have shown conclusively that beet sugar is quite as satisfactory as cane from every point of view" in the preparation of syrups for fruit canning. It has also been found the equal of cane candy for feeding bees. Housewives, however, who attempt to economize by using too little sugar per pound of fruit when making jam or fail to concentrate the mixture sufficiently will probably have disappointing results. They should not, therefore, blame the origin of the sugar. The terms "cane sugar" and "beet sugar" are really meaningless except as an indication of origin. To-day but for our Home Grown Sugar Industry we should be experiencing a sugar famine.



## Early Experiments

The sugar beet plant has been well known for hundreds of years. *Beta vulgaris* or sugar beet is believed to be a descendant of the wild form *Beta maritima*, which is usually found growing near the sea-shore both in this country and in many parts of the Continent. Reference is made to the plant in ancient Roman history. Pliny wrote that "next to grain and beans there is no more serviceable plant than the white beet. The root is used for human and animal food, the young sprouts as a vegetable, and the leaves as an accessory to fodder." Its sugar yielding property seems to have been first noticed in the sixteenth century.

A Prussian chemist named Marggraf was the first to succeed in extracting and crystallizing sugar from beet. That was in 1747. Experiments went on in that country, until in 1799 a specimen of white sugar was obtained. It was presented to the King, who gave enthusiastic help to the establishment of the first sugar beet factory. The percentage of sugar they managed to extract then was about a quarter of what it is to-day.

A big step forward was made in the Napoleonic Wars. France was blockaded by the British fleet and Napoleon at once saw the tremendous advantage of having a supply of sugar produced at home. So he decreed that sugar beet must be grown by the French farmers, and within 15 years over 200 small factories had been erected.

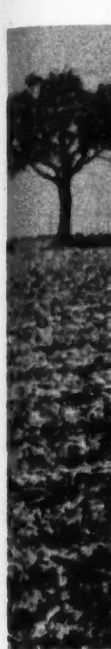
To-day in this country history is repeating itself. Sugar beet is a compulsory crop, and the product of 50,000 farms is contributing to the sugar supply of the nation an amount equivalent to the whole of the domestic ration. The saving in terms of shipping is tremendous. But this is not all. The by-products of the sugar beet crop and the manufacture of sugar from beet are very valuable to agriculture. An acre of sugar beet should produce about 1½ tons of sugar

FIG. 2.—A sugar beet is a miniature sugar factory. The leaves absorb  $\text{CO}_2$  from the air and combine with moisture drawn up from the roots to produce sucrose. The sugar thus formed is stored in the root.

for human consumption, 10 tons of tops and crowns for cattle food, and 1 ton of dried sugar beet pulp having a feeding value equivalent to 8 tons of mangolds. From the factories come thousands of tons of carbonate of lime produced in the purification of the juice. This is sold to the sugar beet grower at a nominal price, is applied to lime-deficient soils, and has made a most valuable contribution to the rehabilitation of arable farming during the last 18 years. In fact, it is true to say that the sugar beet crop was primarily intended to benefit British Agriculture and the history of its establishment as one of the key crops in arable farming is a record of achievement second to none in the annals of British farming.

Dating from 1832, on a site near Maldon, Essex, and subsequently elsewhere, attempts were made to inaugurate this promising industry in the United Kingdom. Although all these early projects came to untimely ends, enough had been done to interest those who had the well-being of agriculture at heart, among them the late Earl of Denbigh. Propaganda for the new crop continued and in due course the interest of the Ministry of Agriculture, the University of Cambridge, and of numerous other bodies was enlisted. It now became certain that Britain would soon have her first modern beet sugar factory.

Yet, strangely enough, when the first modern factory was erected (at Cantley, Norfolk, in 1912) it was under Dutch auspices. It operated at a loss until 1915, and the company was wound up a year later, when the factory was acquired by the English Beet Sugar Corporation Limited. It was re-opened in 1920.



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## Agriculture

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FIG. 3.—Harvesting the Sugar Beet Crop. An acre of sugar beet can produce 8000 lb. of sugar, enough to supply the war ration for 13,600 people for one week. The tops are valuable stock food.

In the meantime, a second proposal—for a factory at Kelham, near Newark, in Nottinghamshire—was mooted. With state assistance, and largely due to the untiring efforts of those who formed the British Sugar Beet Society, an organization established to investigate the possibilities of the industry, a factory was erected on the Kelham Estate and opened by Home Grown Sugar, Limited, in 1921. It did not operate in 1922, but its beet were processed by the Cantley factory. The two worked under a partnership agreement in 1923. A year later a further factory—at Colwick in Nottinghamshire—came into the field.

Due to the financial losses which the earlier schemes suffered, representations were made to the Government for the remission of the Excise Duty on sugar. This was granted for a brief period, and upon its re-imposition and the provision of direct Exchequer assistance by way of subsidy in respect of the 1924 crop, further factories were erected. To-day there are seventeen beet sugar factories in England and one in Scotland.

In 1936 the various companies operating the original factories were amalgamated under the Sugar Industry (Re-organization) Act. The new organization known as British Sugar Corporation was capitalized at £5,000,000. The Chairman and at least two members of the Board are appointed by the Government. This was the first example of a Public Utility Corporation formed to process a home-grown farm crop and distribute the finished product to the trade and through them to the consumer.

## Agricultural Aspect

Sugar beet has done considerably more than merely take its place among the crops regularly cultivated by the

British farmer. It has become so interwoven in the whole fabric of farming that in an ever-increasing number of cases it may be described as the pivot of the farm.

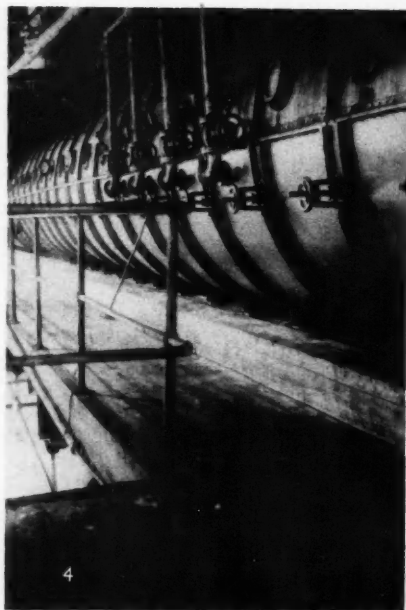
Sugar beet seed is sown from late March to the end of May depending upon season and locality. Generally speaking, early sowing gives the farmer the best results in terms of yield of sugar per acre. Harvesting is carried out from mid-September onwards. The maximum maturity of the crop is reached by the middle of November, after this a decline of sugar content can be expected. Under normal conditions harvesting should be completed by the middle of December.

Deliveries of beet to the factory are made by rail, road and water and are carefully regulated by the factories to avoid congestion or alternatively, a shortage of supplies. The period of operation of the factories is called by beet sugar technologists the "Beet Campaign" and when the acreage is great and the yield good it may extend from October until well into February.

In considering the growing of sugar beet, attention should be given to the following aspects of the crop.

Firstly, it is a cash crop. Over a period of years, taking into consideration the absence of market fluctuations, well cultivated sugar beet is probably the most reliable crop available and one which yields a reasonable cash profit.

Secondly, there are the indirect values. Good husbandry is founded on periodical "fallowing", or improving the condition of the soil. The old-fashioned methods, though eminently suitable in their day, have proved impossible under the present economics of agriculture. Thus various



FIGS. 4 & 5.—Two views of the continuous diffusion process. Here, by the process known as osmosis, the sugar beet cossettes give up their sugar. This goes into solution with the hot water circulating in the diffuser in the opposite direction to the cossettes.



FIG. 6.—The first two vessels of a quadruple effect evaporating plant. Here the thin juice is boiled down to a syrup ready for crystallization in sugar pans.

alternatives are being tried out, as for instance three- and five-year leys. If the risk of obtaining satisfactory plants is successfully overcome, these do improve the condition of the soil; but their greatest exponents can scarcely claim that they clean it. Mechanized cultivation, in favourable seasons, enables cleaning to be done in the minimum of time, and in consequence may replace slower methods. But mechanical cleaning in itself does not improve the condition of the soil.

Sugar beet—a cash crop properly cultivated—does both. Admittedly, the work entailed in cleaning must be performed in the early autumn and not left until the spring, but this is merely a re-arrangement of work. This statement, of course, assumes that the fallowing occurs sufficiently often in the rotation to avoid the need for extensive cleaning.

Beet conditions the soil in two ways: (a) by the crowns and leaves being fed on the ground or ploughed in. These should weigh from 8 to 10 tons per acre; and (7) by the extensive system of fibrous rootlets which permeate the whole of the soil to a considerable depth.

The crowns and leaves can be utilized in two ways: either ploughed-in as green manure, or fed to cattle and sheep. By comparison with reasonable average prices of artificial manures 8 tons of wilted crowns and leaves ploughed-in would return to the soil, on analysis, plant food to an approximate value of £2 per acre.

Beet tops, weight for weight, have a higher feeding value than mangolds, swedes, or turnips. The care exercised in handling influences considerably the food value per acre, but in areas where sugar beet has almost entirely replaced ordinary root crops it has been found that 1 acre of tops,

properly folded, provide as much sheep keep as  $\frac{3}{4}$  acre of white turnips.

The uninitiated may fear that if they replace ordinary roots with sugar beet it will reduce their stock-carrying capacity. Nothing could be further from the truth, however. Successful beet growers have proved that the introduction of beet into the rotation enables them to carry more stock.

## Chemical Aspect

Now it is not generally known that the substance which we call "sugar" is but one member of a large group of compounds known as "sugars" and these in turn, are a particular branch of a very large family of natural products called "carbohydrates" of the general chemical formula  $C_x(H_2O)_y$ . Thus the sugar which appears on the breakfast table, and which is purely organic in character, stands in relation to the "sugars" in the organic world as does "salt" or "common salt" in the salt-cellar to "the salts" of the inorganic or mineral realm. Sugar, then, being a carbohydrate is composed of the elements Carbon, Hydrogen and Oxygen as the generic name implies, the Hydrogen and Oxygen atoms being present in the proportion in which they are combined together in water. The simplest sugar would, therefore, have the formula  $CH_2O$ , i.e.,  $x = y = 1$ . This substance called formaldehyde is a gas and its presence has been demonstrated in certain growing plants. It is claimed by some that this is the first stage in the formation of all carbohydrates, including sugar of course, in plants. Be this as it may, the carbon is undoubtedly obtained from the carbon dioxide of the air which plants



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FIG. 7.—Sugar boilers at work by their vacuum pans. In these pans the syrup is crystallized into sugar in the form "massecuites".



FIG. 8.—The mixture of crystal sugar and molasses is dropped into the centrifugals. Here it is revolved at high speed and the molasses are drawn through a fine mesh leaving, at last, pure sugar in the pan.

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breathe through the stomata in their leaves, and the water is absorbed from the soil through the roots. Combination takes place by the action of sunlight through the agency of the chlorophyll or green colouring matter in the leaves, a process known scientifically as "photosynthesis", the chlorophyll acting as a catalyst.

The simple carbohydrates containing two, three, four, or five of these  $\text{CH}_2\text{O}$  groups combined together are called bioses, trioses, tetroses and pentoses respectively, and when six groups are combined we get a hexose of which glucose, or brewer's sugar, is the commonest example. Hexoses seem to have a liking for combining together themselves and are, therefore, called monosaccharides, two such monosaccharides as for example glucose and fructose (fruit sugar) when combined together lose one molecule of water and form a disaccharide such as sucrose. This sucrose is the sugar with which we are all familiar, and is the one obtained from the sugar beet, sugar cane, and other natural sources. Sucrose is its scientific name. But although sugar as we know it is in all probability built up in this apparently simple way in plants, all attempts to synthesize it have so far been unsuccessful, except perhaps in minute quantities. Many of the simple sugars have, however, been produced artificially but not on a large scale. How wonderful the processes of nature are! We plant a beet seed in fertile soil and with no further assistance beyond a little cultivation a sugar beet plant develops with a root eventually weighing over a pound (sometimes very much more than this) and containing 17% to 18% of sugar and often over 20%. Prize-winning crops of sugar beet have produced in this country (1929) an average per acre of over

8000 lb. of sugar. As 85% of this can be extracted in the form of granulated sugar this means enough sugar from one acre to provide 13,600 people with their weekly war ration!

From what has been said already it is obvious that whether our sugar is presented to us in a sugar beet plant, in a sugar cane, a maple tree, or in any other way it is one and the same substance, namely, sucrose. In the pure state, i.e., as granulated sugar or in any other fully refined form, it will not reveal its origin either by taste, in appearance, or when used. There is certainly, as yet, no chemical test which will tell you so either.

If you visit a beet sugar factory you will see the roots being tested for sugar content in an instrument known as a saccharimeter which simply means a sugar measurer. It puzzles most people who see it as to how it works, and why a beam of light can be made to reveal the percentage of sugar in a solution. Now white light travels in waves of all lengths and in all directions. One wavelength only is required, and yellow light (e.g., from a sodium lamp) is found to be most suitable. In one end of the instrument is a Nicol prism which makes the light waves vibrate in one plane only and the light is then said to be plane-polarized. For this reason the instrument is often referred to as a polarimeter. Now most of the sugars are what we call "optically active", and those which have this property will twist or rotate the plane of polarization of the light either to the left or to the right. They are said to be laevo- or dextro-rotary. Imagine a wave coming through the instrument towards you and vibrating between, say, 12 o'clock and 6 o'clock on an imaginary clock face, i.e., vibrating in a vertical plane. If it comes through a sugar

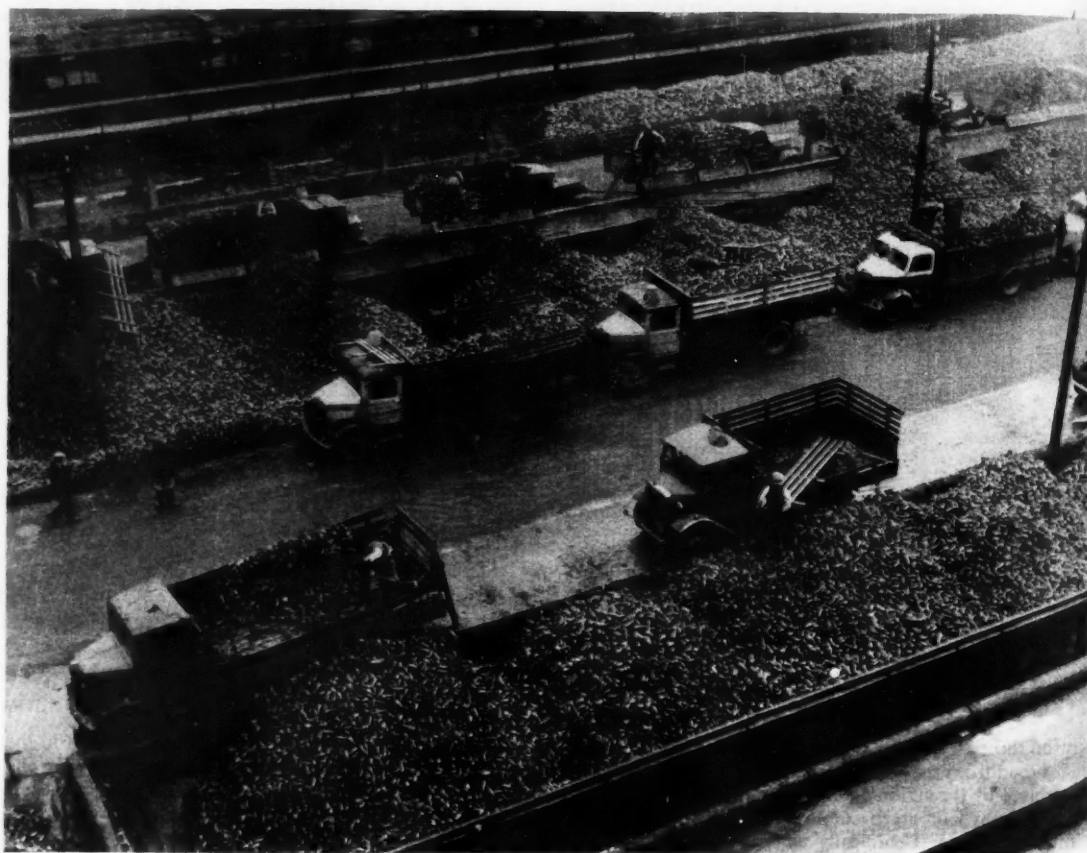


Fig. 9.—A general view of a beet sugar factory yard showing lorries unloading into the silos. A beet factory requires about 20,000 acres of beet annually to run economically.

solution its plane of vibration may be twisted either clockwise or anti-clockwise (depending on the sugar in the solution) by the time it reaches your eye. Ordinary sugar is dextro-rotatory so that the plane of polarization in that case is always clockwise, i.e., from 12 o'clock to 1, 2, 3 and so on o'clock. The extent of the turning or rotation of the polarized light depends also upon the *amount* of sugar in the solution, i.e., the percentage present. Saccharimeters are used in all sugar laboratories for this purpose. By turning a knob the actual percentage present can be read on a scale, providing a certain standard procedure is adhered to for preparing the solution for testing. The instruments are very sensitive and can easily be read to  $\pm 0.05\%$  of sugar.

## Processing the Sugar Beet

The manufacture of the sugar from the sugar beet is quite a complicated process and needs careful chemical control because the sugar beet plant, in addition to producing sugar, produces also a variety of other substances both organic and inorganic. These "non-sugars", as they are called, contain about 73% organic and 27% inorganic

(or mineral) matter. Most readers will probably be familiar by now with the appearance of a sugar beet. It is a whitish, parsnip-shaped root, and while growing has a wealth of broad green leaves and stalks surmounting the crown.

These leaves, stalks and crowns are removed in the fields and only the roots are sent into the factory, since the sugar is practically all found in the roots.

There are four main stages in the manufacturing process:

- (1) Extraction of the sugar from the roots.
- (2) Defecation and Purification of the raw juice.
- (3) Concentration of the purified juice.
- (4) Crystallization of the sugar.

Each of these stages will now be briefly described.

(1) The extraction of the sugar from the roots depends upon a phenomenon known as "osmosis" or "dialysis" which operates in this way. When solutions of solids in liquids are concentrated some solids, like sugar and salt, separate in definite geometric shapes or crystals, while others, such as gum and glue, are amorphous, i.e., have no definite shape and are said to be uncrystallizable.

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If a solution containing a mixture of crystallizable and uncrystallizable substances is separated from a quantity of pure water or a less concentrated solution by a semi-permeable membrane, the crystallizable materials will pass through the membrane much more quickly than the uncrystallizable substances. In other words, the former diffuse much more rapidly than do the latter, and this method of separating the two is known as "osmosis" or "dialysis". This is what happens in the diffusion battery at the factory. The cells of which the beet are composed contain the sugar and other substances both crystallizable and uncrystallizable in solution. The cell walls themselves act as the membrane through which the sugar diffuses into the surrounding liquid.

In practice the washed roots are cut up into thin string-like slices by special machinery which is designed to give the largest possible surface for diffusion. These slices or "cosettes" are long and thin when properly prepared. They are fed into large vertical cylindrical vessels or cells of the diffusion battery, each cell holding several tons of cosettes (generally 3 to 4 tons). Hot water is circulated through the vessels in series so that as it passes from vessel to vessel it gets richer in sugar until it reaches something like 12% to 13% sugar in the last cell. It is then drawn off and is called diffusion juice or raw juice. Sometimes a continuous process is employed, and in that case the slices are fed into one end of a very long horizontal cylindrical vessel containing many compartments along its length (about 22) and the hot water enters from the opposite end to travel counter-current fashion against the cosettes which are passed from compartment to compartment by rotating conveyor arms. In some factories the cosettes are first scalded and some juice expressed prior to the diffusion process thus giving a raw juice of greater density. Normally the raw juice contains about 14% solid matter so that if 12.5% is sugar the ratio of sugar to total solids

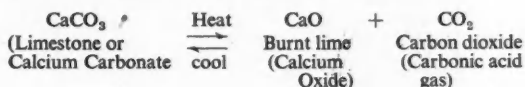
is  $\frac{12.5}{14.0} \times \frac{100}{1} = 89.3\%$ . This is called by sugar technicians the "purity" of the juice. Juice purities are determined at practically every stage of sugar manufacture, and play an important part in the chemical control of the process. During slicing many of the juice cells in the beets are disrupted and the whole of their contents are discharged into the raw juice. Bodies called enzymes are thus released and rapidly attack certain constituents of the juice. In contact with air oxidation products are formed and these impart to the juice a dark grey colour.

The exhausted cosettes still contain a small percentage of sugar when they are discharged from the diffusion batteries. They are dried in specially constructed driers, generally mixed with molasses, and in the dried form are

sold as "dried beet pulp" for cattle food. Beet growers get an allocation of this dried pulp according to the tonnage of beet delivered for feeding their stock. It is much sought after by dairy farmers as it improves the milk yield. The table in the previous column shows typical average analyses of dried beet pulp compared to mangolds and swedes which the sugar beet crop usually replaces.

One ton of dried beet pulp is equivalent to approximately 8 tons of mangolds and swedes and, as a substitute for cereals, to about 1 ton of oats, 15½ cwt. of barley, or 13½ cwt. of maize.

(2) We can now consider the second stage of the manufacturing process, namely, the treatment of the raw juice. Defecation is effected mainly by means of lime which is produced on the factory site by burning high-grade Buxton limestone mixed with coke in large lime-kilns. The reaction which is as follows:



is a reversible one so that the  $\text{CO}_2$  gas has to be and is in fact withdrawn continuously by means of a large pump. It is used in the carbonatation of the defecated juice. The lime is added to the raw juice hot and as a rule in the form of lime cream or milk of lime as it is sometimes called. This is simply burnt lime (calcium oxide) slaked with water (washing water or "sweet water" from the filter presses usually) to the consistency of a cream. The raw juice is heated prior to defecation by lime. Normally about 2% of CaO on the weight of beets is used, but the amount has to be varied according to conditions. Other re-agents are often used in addition such as soda ash, Kieselguhr and decolourizing carbon. Lime is, however, the main defecating agent. It precipitates most of the organic impurities, including colloids, found in the raw juice and is always used in excess of the theoretical requirements as this helps the subsequent filtration. The excess of lime is precipitated by the carbon dioxide gas pumped from the lime-kilns into the limed juice to the optimum precipitation point technically known as the "break". At this stage the gassing is stopped and the mixture filtered through plate and frame presses whereby the precipitated lime (now carbonate) together with impurities are removed. The juice issues from these filter presses as a light straw coloured liquid. It still contains an excess of lime (about 0.06 to 0.8 gm. CaO per 100 mls.) and a further "carbonatation" reduces the alkalinity to about 0.015% CaO per 100 ml, when it is filtered again. By employing two stages of carbonatation much better purification of the juice is obtained.

From this point onwards there is generally pH control because during the carbonatation stages just described a good deal of decomposition of certain nitrogenous compounds takes place with the production of ammonia. This constitutes the so-called "volatile" or "disappearing alkalinity" and as the amount varies in the juice from time to time alkalinity determinations can be, and are, in fact, very misleading.

The third stage in the purification of the thin juice (now containing 11% to 12% of sugar) is treatment with sulphur dioxide gas ( $\text{SO}_2$ ). This both bleaches the juice and

%	Plain Dried Beet Pulp.	Molassed Dried Beet Pulp.	Mangolds.	Swedes.
Moisture	10.0	10.0	88.0	87.0
Crude Protein	8.9	10.8	1.1	1.3
Fats	0.6	0.4	0.1	0.1
Crude Fibre	18.3	15.1	0.9	1.1
Carbohydrates	59.1	58.2	9.1	9.5
Mineral Matter	3.1	5.5	0.8	1.0
	100.0	100.0	100.0	100.0

All figures are approximate percentages

reduces it to the correct pH, usually about 8.0 certain organic impurities are also precipitated and are filtered off. The elimination of impurities up to this stage is something like 45% to 50%. The lime, after use in the defecation of the juice, is stored in large ponds or pits and is allowed to air-dry, and being in the carbonated form it is very safe to use for agricultural purposes. As has already been mentioned, thousands of tons are sold to beet growers every year at a nominal price for liming their land. In addition to the high lime content there are present small quantities of other valuable fertilizing agents such as organic matter, nitrogen phosphates, potash, etc., as seen in the following typical analysis:

TYPICAL ANALYSIS OF FACTORY CARBONATE OF LIME  
(when completely dried)

Carbonate of Lime .. ..	75.9%
Organic Matter .. ..	12.8%
Nitrogen .. ..	0.3%
Phosphate of Lime .. ..	2.2%
Potash .. ..	0.2%
Other Mineral Matter, etc. ..	8.6%
<b>TOTAL .. ..</b>	<b>100.0%</b>

The material transported from the factory ponds to the farms usually contains a fair proportion of moisture, but much of this disappears if the lime is allowed to air-dry still further in small heaps on the fields.

(3) Concentration of the purified juice takes place in multiple effect evaporators and, owing to the large amount of juice to be evaporated (say 120% of the weight of beets sliced), these must be very efficient in design or the operation will prove too costly. About 100 tons of water have to be evaporated for every 100 tons of beets sliced. Thus a factory slicing 3000 tons of beet a day (24 hours) would have to evaporate something like 672,000 gallons of water a day. As a general rule there are four stages (quadruple effect) or five stages (quintuple effect) in the evaporating process and what happens is this. The bottom belt of each vessel or body is a calandria or steam chest fitted with numerous tubes either horizontally or vertically positioned and round which, or through which, the juice circulates and is kept boiling by steam or vapour passing along the other side of the tubes. The bodies are connected up in series so that the vapour boiling off the juice in the first body is led into the calandria of the second for boiling the juice that body contains and so on. The last vessel is connected to a condenser and a vacuum pump to reduce the pressure (and therefore the boiling temperature), as the juice becomes more and more concentrated in passing from vessel to vessel. This is done to avoid caramelization (i.e., oxidation), and consequently loss of sugar. The concentrated juice in the last vessel is usually boiled under approximately 26 ins. of vacuum and contains about 65% of sugar.

Practically all the machinery in a modern beet sugar factory is electrically operated, including the numerous pumps which handle the juices. Factories are equipped with their own power-units and the exhaust, or second-hand, steam from these is used in the first vessels of the evaporators. A considerable economy is thus effected. The condensed steam in the calandria of the various bodies is all returned to the boilers so that very little "make-

up" water is used and there is very little danger of scale formation. During the evaporation of the juice further impurities are thrown out of solution and as there is a certain amount of re-colouration by oxidation, etc., the concentrated, or "thick" juice is often treated again with  $\text{SO}_2$  gas before being re-filtered. It is then ready for the sugar boilers.

(4) We now come to the final stage—the crystallization of the sugar. This is done in vacuum pans fitted with calandrias usually and these are heated by vapours drawn from one or other of the evaporator "effects". A charge of thick juice is drawn into a pan and is boiled down (i.e., concentrated) to the "graining point". This is the point where very tiny crystals of sugar appear, glistening like diamonds when a sample is withdrawn on an inspection glass and held to the light. These almost microscopic crystals are then made to grow by feeding the pan with more thick juice at regulated intervals until when the pan is full the crystals are of the size required in the finished sugar. The sugar boiling is done under reduced pressure all the time and when the crystallization is complete the mixture is known as a "massecuite". An average pan will produce about 45 tons of white massecuite in about  $2\frac{1}{2}$  hours from the time it is charged. A "white" massecuite may be pictured as a hot viscid agglomeration of white sugar crystals embedded in a light brownish coloured mother liquor. The pan or "strike" when ready is dropped into a receiving vessel or "mixer" from which it is fed, while still hot, into centrifugal machines, revolving at 900 to 1000 revolutions per minute. The mother liquor is thereby spun off and the gleaming white sugar crystals remaining on the baskets of the machines after washing with hot water are discharged and conveyed to special driers or "granulators". They are then cooled, sometimes screened to definite sizes and bagged as granulated sugar. Sugar boilers can produce any size of crystal required.

The mother liquor or "run off" separated as just described is boiled up again in another pan set aside for the purpose, and produces a further crop of crystals, this time "raw sugar" or "crystallizer sugar" according to the quality or "purity" of the liquor. This lower grade of sugar is re-melted, i.e., dissolved in hot water or hot juice and this is mixed with fresh thick juice from the evaporators to produce more white sugar. The run-off from the lowest grade pans, although it still contains something like 50% of sweetening matter, will not crystallize further without special treatment, and is known as molasses. As a result of recent research work it is interesting to note that beet molasses can now, under special conditions, be fermented to produce quite appreciable quantities of glycerine—a very useful chemical in war-time, as it is the basis for certain types of explosives. Some of the factories do not take their sugar right through to the "refined" stage. Their output is bagged as raw sugar and is sold to refineries or else stored in their own warehouses and refined by their own factories during the summer months. As a war-time measure some factories have produced an industrial grade of sugar instead of the raw sugar which has to be refined later before it can be used. This "Industrial Sugar" is a slightly lower grade of granulated sugar than ordinary white sugar but still suitable for general manufacturing purposes. In this way many hundreds of thousands of

ton-miles have been transported by rail and an important

## Research

Research about greater and the cultivation of the Sugar on which the Farmers' Un-

ton-miles have been saved in transport alone in a year—an important consideration at this time.

### Research Work in the Industry

Research work is continually being carried on to bring about greater efficiency both as regards the factory process and the cultivation of the crop. A composite body known as the Sugar Beet Research and Education Committee on which the Agricultural Research Council, the National Farmers' Union, and British Sugar Corporation are repre-

ented conducts many phases of experimental work and disseminates educational matter to growers year by year. Growers have, moreover, the assistance of factory representatives. At each factory an agriculturist and a staff of fieldmen are closely in touch with the farmer growing beet. They advise on the treatment and cultivation of the soil, choice of fertilizers and seed, and, indeed, with every problem including labour, transport, etc., from the time the grower signs his contract until the beet is safely delivered to the factory.



FIG. 10.—A sugar store in an English beet sugar factory.

# Russian Research on Potatoes

N. ELIZOV

A LITTLE while ago I lunched with A. Rodionov, Rector of the All-Union Institute of Selection and Genetics. This is the Institute where the leading Soviet biologist Trofim Lysenko, now President of the Lenin All-Union Agricultural Academy, carried out his famous researches into the theory of the stage-by-stage development of plant life and the vernalisation of agricultural seeds. A large dish of boiled potatoes was placed on the table before us. All this took place in Kibrai, not far from Uzbek, the capital of Tashkent, where the Institute had been evacuated from Odessa.

I was a little astonished at the appearance of such a "dish" on the table of the Rector of a scientific research institution; but the other guests, mostly workers in agricultural research institutions, greeted it with exclamations of approval.

Then Rodionov told me an interesting story of how the Institute is working on the solution of an important problem.

Any gardener knows (and the fascinating story is told in Rodionov's words) that a potato tuber before it will begin to sprout must undergo a certain period of rest. This is usually quite a long time, sometimes as long as several months. That is why only potatoes from a previous year's crop are usually planted.

Many scientists in different countries have worked on the problem of forcing the potato to reduce its rest-period but so far none of the proposals made has been of any practical value. They were all too intricate. Several of them, for example, required that tubers be gassed with various gasses the cost of which far exceeded the results achieved. But the most important thing of all was that even when these methods were employed, only a small number of tubers actually grew.

The solution of such a problem would have great economic significance. This is particularly important in southern districts where cultivation of the potato is accompanied by its "deterioration". Academician Trofim Lysenko has shown that this degeneration can be overcome by planting potatoes in summer so that the formation of the tuber takes place in the autumn when the hot season is already past.

The application of this method in Central Asia and the Transcaucasus easily accounts for the fact that seed

potatoes are difficult to preserve till summer because tubers rot in the heat. If it were possible to plant potatoes in the same year as they are grown then the necessity for keeping them would no longer exist. This problem also was tackled by Lysenko, who analysed the reasons why potatoes will not sprout in the same year as they are grown and discovered that in order to reduce the rest period of potatoes air must be allowed to get at the fleshy part of the potato.

Practical tests vindicated Lysenko's opinions. If potatoes are lifted before the skin has had time to thicken and the skin is scratched and then the potatoes are laid on the ground and covered with a thin layer, two to three centimetres deep, of damp pliable earth, the potatoes will soon begin to sprout and may be planted in the usual way. Some sorts of potatoes begin to sprout within three to five days. In order to scratch the skin it is sufficient to stir potatoes together in a barrel of water.

At the present moment the Institute is working on the simplification of methods of obtaining two potato harvests in a year from one batch of seed potatoes.

The work of the Institute of Selection and Genetics is entirely devoted to the agriculture of districts lying far in the interior of the Soviet Union. For the first time this year thousands of acres of sugar beet were sown in Uzbekistan in order to compensate for the temporarily lost sugar producing regions of the Ukraine and Central Russia. Working on proposals made by Trofim Lysenko, the Institute has proved that it is not only possible to sow sugar beet in spring in Uzbekistan as in the Ukraine, but also in summer and on land which has already borne a grain crop such as wheat or barley. The summer sowing of sugar beet in Uzbekistan will enable us to obtain two different sorts of valuable crop from the land each year.

Institutes are also preparing large quantities of seeds of special sorts of wheat, barley and cotton intended for southern regions of the Ukraine and developed by Academician Lysenko before the war. These new kinds of grain are greatly superior to any types previously existing.

Our task is to be able to give collective farmers of the liberated regions seeds of the new valuable crops which we have developed, said A. Rodionov in conclusion, and we have to hurry with this task for we are firmly convinced that the hour of the final defeat of Hitler is not far away.

## MONTHLY NOTEBOOK—cont. from p. 164.

out with flying colours, and he paid tribute to the basic work of the research scientists on which these theories had been based. The free or cheap distribution of milk and vitamins begun in this country as a war-time measure were the most important single public health measure which had yet been taken.

Mr. F. le Gros Clark, secretary of the Children's Nutrition Council, supported Dr. Magee's statement, and

said that these distribution schemes set a very important precedent. Now, for the first time, foods were being distributed according to biological need and not according to ability to pay. He said that 90% of the mothers entitled to free or cheap milk for their children were taking advantage of these facilities, but that only 30% of those entitled to fruit juices were in fact taking them. It was however a healthy sign that this latter percentage was increasing.

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# Feeding the American Army

## A COMMUNIQUÉ FROM THE U.S.A.

THE U.S. Army's Experimental Kitchen, officially called the Subsistence Research Laboratory, is a part of the U.S. War Department's Quartermaster Depot at Chicago, Illinois. It is the only one of its kind in the U.S.A.

The old saying that the army marches on its stomach is true to only a limited extent. The army to-day not only marches, it also runs, rides, flies, jumps from great heights, scales mountain peaks, skis and swims; it is an army that must fight and live in arctic, tropic and temperate zones; it must travel quickly and wage battle thousands of miles from home stations; its lines of supplies become equally long and sometimes, because of the swift, sudden changes of battle lines, entirely disappear. Hence, the army to-day must and is prepared for every eventuality; it must and is prepared and equipped to sustain itself for long periods of time and under all conditions of battle and weather.

Food is and always will be an important part of mankind's daily life; and in the armed forces of to-day, when life and death run hand-in-hand, food is doubly important, for wholesome, nourishing foods are conducive to health and life. Food for consumption of the armed forces meets the highest standards of quality set by man; it must be suitable, palatable, as well as fill the needs of human nutrition. Army food must furnish energy, build and repair body tissues, and keep the body in a continuous state of sound health.

Of course, these are rudimentary requirements that have been preached by dieticians, civilian and military, for years and to some extent have been universally accepted and practised by millions of Americans. However, in the feeding of millions of American soldiers, the U.S. Quartermaster Corps must be sure at all times that the foods served not only meet the above-mentioned qualifications, but must make certain that they meet the wants of the armed personnel while achieving a balanced diet, since no person likes the same foods over and over again no matter how good they are for the proper functioning of the human organism.

In each balanced diet as used in the U.S. Armed Forces, particular pains are taken that the correct ratio of carbohydrates, proteins, vitamins, fats, minerals, and bulk exists except in rations that are developed for emergency conditions. So that a balanced diet can be put into practice at every meal, the army has set up some very simple rules. It is not always possible to keep a balanced diet in every meal or each day's menu, but any lack is corrected within a meal or two.

### Balancing the Vitamins

The health-protecting elements about which the army is chiefly concerned are vitamins. Ordinarily troops in combat will receive sufficient vitamin A and vitamin B, but there may be danger of an insufficient vitamin C (the anti-scurvy vitamin). This is because vitamin C is readily

destroyed in ordinary cooking whilst vitamins A and B are not. Vitamin C is furnished chiefly by fruits and vegetables, and considering the fact that some of the typical rations scheduled in the master menus based on a week contains about 10 lb. of vegetables, two oranges and in some instances a whole grapefruit, the U.S. Armed Forces are assured of plenty of vitamin C. Incidentally, vegetables and fruits also are the most valuable sources of minerals and bulk.

As the trends toward concentrated and dehydrated foods increase, the vitamin consideration becomes more and more vital. Hence, the staff of the Subsistence Research Laboratory at the Chicago Quartermaster Depot is devoting a great deal of time in searching and developing new approaches to vitamin analysis and induction. Much valuable data has been gathered and many of the vitamin discoveries have been put into practice.

There are three distinct types of rations with subdivisions now being served to the armed forces—garrison, field, and emergency. Each type of ration (ration is the allowance of food for one person for one day provided by the Government for the subsistence of soldiers and other authorized personnel) is planned and developed to fit into the needs of the individuals consuming them. These rations are composed of fresh foods, canned foods, and concentrated foods.

The garrison ration is just what its name implies. It is the ration or menu consumed in garrison in time of peace, based on money values.

These are two designations to the army field ration—it is referred to as the "A" or "B" ration. When the field ration contains fresh meat and fresh (soft) bread, it is referred to as the "A" ration; when it contains canned meat and hard bread, it is designated as the "B" ration.

Field rations are planned for periods thirty days in advance. This assures a balanced diet, variety, and control of foods. Emergency ration is given to the armed forces when they are far removed from the facilities of regular field kitchens or established mess units.

The "D" ration consists of three 4-oz. bars of concentrated chocolate. Its primary purpose is to give sustenance to the armed forces in times of extreme duress, stress, and when out of touch with bases of supply for short periods of time; it is also planned to give troops extra energy when engaged in continuous combat, and regular eating time is not permitted.

The "D" ration concentrated chocolate bar is made up of chocolate, sugar, skim-milk powder, cocoa fat, oat flour, vanillin, vitamin B, and 150 I.U. The "D" ration has been included in a small way in the army field ration "C" which followed the development of the "D" ration.

Field ration "C" consists of previously cooked or prepared food, packed in sealed cans, and may be eaten hot or cold. Each ration consists of three cans of meat and vegetables and three cans of crackers, biscuits, confection, sugar and soluble coffee.



FIG. 1.—Making a moisture analysis in a vacuum oven. FIG. 2.—Precision tests are made of certain foods: here laboratory technicians are scrutinizing results of an assay. FIG. 3.—Making a Penetrometer test. FIG. 4.—The Army Field "K" supper ration. FIG. 5.—The Army Field "K" dinner ration. FIG. 6.—This is the ration with which Army jungle fighters are supplied.

## DISCOVER

In the field, dried onion are used. I wholesome

## High C

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The army the parachute the attention exhaustive armed force only in time regular me advisable.

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Coffee (fr is purchase master Dep and grinds are shipped are prepared who have a most of the more chicor

Coffee in powder for treated pack hydrates. It is prepar

In the field ration "C" only choice cuts of beef and pork are used. In the hash and stew will be found Irish potatoes, dried onions, carrots, white beans, tomato juice, and clean, wholesome spices.

## High Coleric Value

The army field ration "K" ration is a distinct achievement of the Chicago Subsistence Research Laboratory. Originally, it was termed the "parachute ration", later labelled the "para-ration", and finally designated as the army field ration "K". Dr. Ancel Keys, Professor of Physiology at the University of Minnesota Medical School at Minneapolis, assisted Colonel Rohland A. Isker in the development and experimental work.

The army field ration "K" was first planned for use by the parachute troops, but certain features of it attracted the attention of high ranking army officers, and after exhaustive tests it was officially accepted for use by the armed forces. It is a concentrated food and will be used only in time of emergency and continuous combat when regular messing facilities are not available or considered advisable.

One of the interesting features of the army field ration "K" is that while it is packed in three separate boxes—one for breakfast, one for dinner, and one for supper—it weighs only 32.86 oz. and yet contains 3,726 calories. Each meal contains the necessary elements to give the proper balance of carbohydrates, proteins, and fat. Proper vitamin content and vitamin retention are also taken into account.

A recent field test conducted on a large scale at Fort Benning, Georgia, U.S.A., proved that the army field ration "K" is a superior emergency field ration which can be subjected to all types of field conditions and all sorts of weather and yet please soldiers with its nutritive and appetite-appeal qualities.

The armed forces to-day enjoy coffee, bouillon, milk, and orange juice, grapefruit juice, lemon juice. In the army field rations "C" and "K" will be found coffee, bouillon, and lemon juice. Where troops are still on the garrison ration there is sometimes included tea and cocoa, but this is more the exception than the rule.

Coffee (fresh coffee is served with "A" and "B" rations) is purchased in the green bean. At the Chicago Quartermaster Depot a large coffee-roasting plant roasts, blends and grinds the best quality coffee beans obtainable. These are shipped to all parts of the country and special blends are prepared for soldiers in different geographical locations who have a cultivated taste for certain blends; for instance, most of the soldiers who originate from the South like more chicory than soldiers from the North.

Coffee included in the "C" and "K" rations is in powder form and is packed in a specially designed and treated packet; some are also treated with added carbohydrates. All are readily soluble in hot or cold water. It is prepared in such a manner that there is no material

change in flavour; aroma, or stimulating properties which is expected of coffee.

Lemon juice which is a component part of the supper unit of the army field ration "K" is in synthetic powdered form: some of its ingredients include oil of lemon, dextrose and corn syrup. It has proved a welcome refreshment and has added considerably to the acceptability of the "K" ration.

The bouillon which is found in the dinner unit of the "K" ration is also a concentrate and is made up of such ingredients as pure beef extract, salt, proteins, and starches. It is semi-plastic and readily soluble in cold water (60°F.) and is packed in a collapsible tube.

## The Laboratory and its Staff

The Subsistence Research Laboratory established at the Chicago Quartermaster Depot is the only one of its kind in America. It is ably headed by Colonel Rohland A. Isker assisted by Major John N. Gage, Major Jesse H. White, Major Charles G. Herman, and a trained and experienced staff of biochemists, physiologists, technical advisers, and specialists. The fame of the laboratory and its works are known the world over, and to it goes much, if not all, of the credit for the improvement of the "D" and "C" field rations and entire credit for the creation, experimentation, development and conclusive proving of the army field ration "K" as to its acceptability and adaptability for armed force food requirements. The working of the Subsistence Research Laboratory is a revelation in modern food analysis and laboratory technique. From every corner of the globe come food specialists, manufacturers, and food samples.

The thousands of food samples which are sent for the analysis and consideration of the laboratory staff with the primary object of their adaptability for regular army use are distributed to the members of the staff on the basis of their specialization. These food samplers are tested for their keeping qualities, for purity, for nutritive characteristics, for taste, suitability. Chemists, physiologists, and other food specialists break down the foods into their various ingredients; packaging experts study the samples for the viewpoint of package construction and other shipping and storage considerations.

Some of the foods are given exacting precipitation, cooking and baking tests, and are exposed to pressure and humidity chambers, storage tests, and other exhaustive examinations. In the laboratory, at any time of the day or night, bacteriologists microscopically study various cultures; others are concerned with enzyme destruction; chemists subject various food samples to colour fade exposures. The Chicago Subsistence Research Laboratory is concerned with fresh foods, canned foods, and concentrated foods; it is occupied with problems of packaging, climates, refrigeration and the many other pertinent phases of keeping foods fresh, palatable, and nutritious. It is doing a big job of work.

# The Night Sky in July

M. DAVIDSON D.Sc., F.R.A.S.

**The Moon.**—New moon occurs on July 2d. 12h. 44m., U.T. and full moon on July 17d. 12h. 21m. The following conjunctions will take place:

July			
4d. 08h.	Jupiter in conjunction with the moon,		
		Jupiter 2° N.	
6d. 16h.	Venus	"	Venus 0°·4 S.
24d. 23h.	Mars	"	Mars 4° N.
28d. 07h.	Saturn	"	Saturn 3° N.

**Occultations.**—The following occultations of stars brighter than magnitude 6 occur, the times referring to Greenwich:

July 6d. 16h. 12·5m.	$\alpha$	Leo	D
6d. 17m. 27·5			R
13d. 21h. 05·7m.	49	Lib	D
27d. 02h. 29·0m.	264	B.Tau	R
27d. 04h. 15·0m.	$\alpha$	Tau	D
27d. 05h. 23·6m.			R

(D and R mean disappearance and reappearance, respectively).

**The Planets.**—Mercury is in superior conjunction on July 18 and is unfavourably placed for observation. Venus can be observed in the evening during the month. The planet sets at 22h. 30m. and 20h. 45m. at the beginning and end of the month respectively, the corresponding times for the sun being 20h. 20m. and 19h. 52m. Mars is in the constellation of Pisces at the beginning of the month but at the end of the month is in Aries and about 4°S. of  $\delta$  Arietis. A curious effect occurs owing to the fact that the planet is moving rapidly northwards in declination. At the beginning and end of July it sets almost at the same time, about 13h. 40m. On the first date Mars is nearly 119 million miles from the earth but at the end of the month this distance has decreased by 15,000,000 miles. Jupiter is in superior conjunction with the sun on July 18 and

cannot be observed. Saturn, in the constellation of Taurus, is a morning star, rising at 1h. 50m. in the middle of the month and setting at 17h. 50m.

In addition to the above phenomena the following are of special interest:

On July 6d. 16h. Venus is in conjunction with the bright star Regulus ( $\alpha$  Leonis), Venus being 0°·4S. Venus crosses the meridian on that day at 15h. 10m., and those who are in possession of a moderate sized telescope should be able to see the conjunction. On the same day at 15h. 44·9m. Venus is occulted by the moon, and at 16h. 50·5m. she emerges from the occultation. This occultation can be observed at Greenwich and Edinburgh. At the latter place the times of disappearance and reappearance are 15h. 42·6m. and 16h. 33·9m. respectively.

Occultations are observed by a certain number of amateur astronomers in this country and the results are very important because they supply the data necessary to correct the computed positions of the moon. The exact instant of the beginning and ending of an occultation can be calculated for any place, knowing the position of the star and also those of the sun and moon. Although the moon's position can now be computed to a high degree of accuracy there are always slight discrepancies between the computed and observed positions and these discrepancies are revealed by the occultations being early or late—at the most a second or two. When a large number of observations have been made in any year and the results have been dealt with by experts on this subject, the corrections to the positions of the moon can then be made. These are very small—only of the order of about a second of arc, but they must be used when the final computations for solar or lunar eclipses are made, to ensure the greatest accuracy.

On July 4 the sun is at its greatest distance from the earth—a little more than 94,500,000 miles—and after this the distance very slowly decreases until January 2, 1944.

## Diphtheria Immunisation

MR. VIANI asked the Minister of Health, on May 18, how many immunised children under five years of age and how many over that age were there in the country at the end of 1941; how many at June 30, 1942, and how many at December 31, 1942; what were the ages of the diphtheria cases in 1941 and in each half-year of 1942, distinguishing between immunised and unimmunised; and what were the ages of the fatal cases of diphtheria, immunised and unimmunised in 1942.

The Minister of Health replied: The numbers of children

immunised against diphtheria under local authority arrangements in England and Wales up to December 31, 1941, were approximately 547,000 under five and 1,818,000 between the ages of five and fifteen. The corresponding figures at June 30, 1942, were 725,000 and 2,114,000; and at December 31, 1942, 1,150,000 and 2,598,000. To obtain the particulars referred to in the last two parts of the question would necessitate a special return from all local authorities which I should not be justified in requiring them to make in view of the labour which it would involve.

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# The Bookshelf

**B.B.C. Year Book 1943.** With a Foreword by Sir Allan Powell (British Broadcasting Corporation, London. 128 pages + 36 illustrations. 2/6 net.)

THE importance of the Radio as an instrument of popularisation of science was stressed at a recent Conference of the British Association, at which this subject, with the Press and the Film, rightly claimed a session of its own. With Sir Allan Powell, one of the B.B.C.'s Governors, in the Chair, and some plain speaking by Sir R. A. Watson Watt, Dr. Darlington and others, one felt that scientists and the B.B.C. had at last got together to find means for the effective presentation of the difficult subject of science to the general public.

Although the *B.B.C. Year Book for 1943* has appeared since that conference, we can hardly expect to find any traces of influence which scientists may have been able to make upon B.B.C. policy in this respect. As Sir Allan says in the Foreword: "This book gives a brief account of how British Broadcasting has developed and been carried on in 1942". Therefore plainly we must examine the book and the policy it describes through historical spectacles. But Sir Allan goes on to say: "The promise of the B.B.C. at its start . . . was that it would maintain in all its work the highest standard of integrity, dignity and truth, that it would be informative and educational in the best sense of those words, and that it would provide good entertainment." After the B.A. Conference, the B.B.C. must know what some of Britain's most eminent scientists think of its attitude towards its efforts to be "informative and educational" about scientific matters. That some scientists have proved themselves first-class entertainers—which is in fact a branch of the humanities in which few people have succeeded only after years of study and practice—speaks well for the future success of science broadcasts when scientists as a body are asked to co-operate in planning and directing them.

But let us return to the work of the B.B.C. in the year 1942, with which this book so successfully deals. The Corporation's wartime task of being at one and the same time an entertainer of, and a publicist for, John Bull was courageously and effectively performed in the year under review. Let there be no mistake about that.

Quite naturally readers will examine the year book critically in the light of his or her particular likes or dislikes. "How many programme hours were given to classical music, to Tommy Handley, to gardening—even to science?" one will ask of it; but in vain. This sort of analysis is not given, but there is a telling picture of some of the handicaps under which broadcasting on the whole was accomplished in 1942.

What must interest a number of readers is the account of the development of overseas broadcasts. This truly is a magnifi-

cent piece of work. Broadcasting to every corner of the earth in one of the 45 languages now spoken by the B.B.C. entails an organisation that must be approaching perfection.

Sir Noel Ashbridge, the Controller of the Engineering Section, writes feelingly upon the difficulties of technically manning the B.B.C.'s stations in war-time. To meet the ever-growing demand for technicians, there is an engineering section embracing over 3,000 men and women. It is interesting to learn that over 500 of the women have qualified as operational technicians; indeed Sir Noel speaks highly of his women engineers. With only one in four of his present technical staff having pre-war experience in B.B.C. service, little imagination is needed to visualise what a task it must have been to continue broadcasting at all—even without other "incidents" of one sort and another to contend with. The Engineering School within the B.B.C., about which the Controller writes with such enthusiasm, has proved a useful experiment during the two years of its existence. It is to be hoped that eventually a research section into pure science as distinct from science directly applied to radio may be added to the B.B.C.'s physical functions.

The little book under review is indispensable for the proper appreciation of the work of the B.B.C. It is as usual informative in a pleasing manner, well illustrated, and fulfils its function of portraying the most important radio activities in Great Britain in 1942. That, as we have indicated, science is not considered by the B.B.C. as important is stressed by the fact that the word does not appear in the book's index, neither as subject-matter for talks nor in its applied form, without which the whole show could not work. It is to be hoped that by the time the next Year Book is reviewed in these columns a Central Science Advisory Committee will have ranged itself alongside the Committees for Appeals, Group Listening, Music, Schools Broadcasting, Religion, etc., and that there will be an entry "Science Broadcasting" in parity with Music, Religion, Schools and other similar broadcasting. P.V.D.

**Haddon the Head Hunter.** By A. HINGSTON QUIGGIN. (C.U.P. 1942; xiv + 169 pages + 6 plates; 7s. 6d. net.)

ALFRED CORT HADDON, anthropologist—or as he preferred it, ethnologist—was for many years an outstanding figure in a Cambridge which had no lack of personalities of marked characteristics. His large, loosely-knit frame, his mentality, and his brusque, if nonetheless genial manner, were far removed from the academic convention. But his penetrating judgment in matters relating to science, as well as his profound knowledge of those aspects of anthropological study which he made peculiarly his own, earned him a well-deserved and world-wide reputation. His integrity and singleness

of purpose, no less than his generosity to workers in the same field as himself, won him the affectionate regard not only of his contemporaries but also of many generations of younger students.

Haddon had not always been an anthropologist. Soon after taking his degree at Cambridge he was appointed, in 1880, Professor of Zoology in the University of Dublin; and it was not until 1888, when at the age of thirty-three he led an expedition of research in marine biology to the Torres Straits, that he turned to what seemed to him then and for the remainder of his life the more urgent problems of the ethnology of primitive and backward peoples and their place in the racial and cultural history of mankind as a whole. The urgency of these problems, which induced Haddon to sacrifice a career in which he already had attained no mean reputation, lay to his mind in the rapidity with which savage customs and beliefs were changing with the impact of a Western civilization. There was also then, a complete lack of properly organized scientific method in the superficial accounts of primitive peoples and their culture, which had passed hitherto for ethnographical observation. The claim which has been made that Haddon was the founder of scientific anthropological investigation in the field is by no means exaggerated. The Cambridge Anthropological Expedition to the Torres Straits of 1898-99, has served as a model and a standard for all subsequent research in the field. In scientific value its results have not been surpassed. For this, however, something must be credited to the skill and judgment with which Haddon had selected the members of his expedition. This is borne out by the names of W. H. R. Rivers, W. McDougall, C. G. Seligman, C. S. Myers, and S. H. Ray, each of whom subsequently achieved an international reputation.

In 1893 Haddon settled in Cambridge. Thereafter his work in teaching and research ran parallel with a struggle to secure official recognition in academic curricula, more especially in Cambridge and London, for a subject which was little understood and therefore the more strongly contemned. His appointment successively as University Lecturer and Reader in Ethnology is some measure of the success of his efforts. The Anthropological School in Cambridge and the University Museum of Archaeology and Ethnology, in which his own collections form the most extensive and scientifically valuable exhibit, are an enduring monument to his self-sacrificing devotion to anthropological science. Those who would wish to follow further the by no means uninteresting story of the birth pangs of a new science may be referred to this brief but excellent sketch of Haddon's long and full life—he died in 1940 at the age of eighty-five years—by Mrs. Hingston Quiggin, who was associated with much of his work over a long period of years.

E. N. FALLAIZE.

# Far and Near

## Royal Institute of Chemistry

HIS MAJESTY THE KING has been pleased to command that the Institute of Chemistry shall, from May 22, be known as "The Royal Institute of Chemistry of Great Britain and Ireland".

## "Pipe Dream" of Future Radio

"A pipe dream" was the phrase which Sir Robert Watson-Watt applied to his strictly personal and unofficial proposals for post-war radio, in addressing the Radio Industry Luncheon Club on May 25, when he discussed in more detail the technical questions implicit in his speech at the British Association Conference on "Science and the Citizen". He demanded a system which would give at least six different programmes which could be completely separated from each other in the receiver, and might be devoted to the two kinds of good music, news and topical talks, educational "cultural" talks, and two other types of programme. The existing system lacked choice because it was based on an unnecessary economy in the means of transmission, and it was liable to several forms of interference, as well as to distortion, because it employed carrier frequencies which had a historical explanation but were not logically suited to the job.

He thought the industry's fear of a piped system of diffusion was not justified, and believed that this was the right solution for every community of 5,000 or more, and possibly for smaller ones, though radiated programmes would be retained in addition for reasons of national prestige and to serve the backbone of the country—the agricultural population. (Distribution by "pipe" would presumably be by "wave-guides" of the type described in the April issue of *Discovery*, p. 98, under the title "Radio Plumbers".) In such a system, the safeguards against undue Government compulsion in the choice of programme, and quality of material, would depend upon a control of the proportions in which different kinds of material were shared between piped and radiated programmes.

In reply to a question, Sir Robert expressed doubt as to the effectiveness of frequency modulation as a 100% answer to interference and distortion problems. In further discussion, Sir Louis Sterling objected to the "pipe" system on the grounds that it would not give freedom of choice of programme, would close down radio research and so cause unemployment, and by reducing the industry's home trade would destroy the basis of an export trade.

In reply to this, Sir Robert pointed out that in any field of entertainment the selection of material offered to the public is made by a very small number of men, and the only way is to insist that those who give us our programmes give all of us some of what we want. In one of his many activities—as a "trade unionist agitator"—he was very keenly concerned with the employment problems of technical men,

and did not admit that the "pipe" system would require less research; it would offer just as large a field for technical and industrial enterprise as the radiated system. But in any case he did not propose to prohibit radiated programmes, and people would still have freedom to choose the bad reception of these programmes if they wished.

## Hydrogen Engine in German Submarines

THE examination of captured Nazi U-boats by Allied naval authorities has resulted in a report that "the usual electric motors, supplied with current from a large battery installation, have been discarded. Instead, the main diesel engines intended for propulsion on the surface are designed to run also on a mixture of oxygen and hydrogen so that, operating with a closed exhaust, they can be used for driving the vessel when the latter is submerged." It is claimed that the Erren engine, as applied to submarines, increases the radius of action, the space available for armaments, and the speed and angle of submersion, in addition to which it eliminates the possible generation of poisonous fumes from the batteries. Moreover, it also provides the locomotive power for a trackless torpedo vehicle, even if it misses, will give no visible indication to the enemy that it has been fired.

The Erren submarine, says a report in *Shipbuilding and Shipping Record*, 1942, 60, 21, p. 495, is driven on the surface by alternative-fuel engines running on oil and driving a small high-speed dynamo which delivers its current to a high-pressure electrolyser by means of which water is broken up into hydrogen gas and oxygen gas in the ratio of 2 to 1 ( $H_2O$ ) under a pressure of 3000-5000 lb./in.<sup>2</sup>. These gases are stored in separate light-weight high-pressure cylinders along the keel. When the submarine dives, the Erren engines are switched over to run on oxygen and hydrogen without any air or oil. The combustion product of these gases is steam, which is put back into the engine at a temperature slightly above the saturation point. Oxygen and hydrogen in the correct ratio and in an amount according to the power output required are injected into each working cylinder separately; the latter is thereupon filled up with the steam and the resultant mixture is fired by means of a spark. The heat generated then superheats the steam, which expands in the usual way and drives the piston.

A considerable amount of experimental and research work in connection with the Erren system was carried out at the works of William Beardmore & Co., Ltd., at Dalmuir. The test unit was a 10-year-old single-cylinder Beardmore engine in which the original compression ratio of 14.8 to 1 had been reduced to 10 to 1. Official tests attended by Government representatives included demonstrations of starting on air and hydrogen, changing over to oxy-hydrogen with closed exhaust, changing over to fuel oil and hydrogen and to

fuel oil alone, and manœuvring at different speeds on various fuels. Demonstrations were also given of the Erren system applied to National single-cylinder diesel engines and to a Beardmore engine in a Leyland 32-seater 'bus. A remarkable increase in efficiency and output was a feature of these tests. It is claimed that the application of the Erren system to a submarine makes it possible to increase the radius of action to more than 15,000 miles, while the saving in weight allows the pressure hull to be strengthened to such an extent as to enable the boat to crash dive at a steep angle and to submerge with safety to a depth of 600 ft., i.e., far below the depth at which the normal depth charge is effective.

## Glass that floats . . .

"FOAMGLAS"—a form of glass which floats like cork—is to be made in Britain. Although production here has not yet reached the commercial stage, foamglas has been marketed for some time in the United States by the Pittsburgh Corning Corporation. The glass, which has a weight of only 10 lb. per cubic foot, is fireproof and vermin-proof. Its lightness—fifteen times that of ordinary glass—is due to the cellular structure being composed of countless tiny air-tight cells. Because of its closed cell structure it can be sawed or drilled with ordinary tools. For the same reason it will not absorb water and will float indefinitely, so that it is a suitable substitute for cork and kapok in the manufacture of lifebelts and buoys. Only the cells in the direct path of a bullet fired through it are destroyed and the rest of the mass will continue to float. It is thus particularly useful for war purposes. It is made by firing ordinary glass which has been mixed with a small quantity of pure carbon; when the glass softens the carbon dioxide produced acts upon the molten glass much in the same way that this gas causes bread to rise.

## The Oldest Plastic

ACCORDING to John Gloag, who lectured on plastics to the Royal Society of Arts on May 26, the first plastic was called *Parkesine*. In 1865 the inventor, Mr. Alexander Parkes of Birmingham, said:

"For more than twenty years I entertained the idea that a new material might be introduced into the arts and manufactures, and in fact was much required; I succeeded in producing a substance partaking in a large degree of the properties of ivory, tortoiseshell, horn, hard wood, india rubber, gutta percha, etc., and which will, I believe, to a considerable extent, replace such materials, being capable of being worked with the same facility as metals and wood. This material was first introduced under the name of parkesine in the Exhibition of 1862, in its rough state, and manufactured into a variety of articles in general use; it then excited the greatest attention, and received a prize medal . . ."

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Parkesine and oil, also other substances of hardness "in the manner by pyroxyline Mr. Parkes recognise as that are known name of Pl refer to his p of the Socie for December he had been of synthetic before the earlier he h bearing on Alexander man, the sc the fertility In many w turous and latter half o formed a became the ing fecundit in many pried in 189 patents, co activities, a jects, electr celluloid, ornamenta

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Parkesine was made from "pyroxyline and oil, alone or in combination with other substances." The various degrees of hardness or flexibility were obtained "in the easiest and most expeditious manner by varying the proportions of pyroxyline oil, and other ingredients". Mr. Parkes described what we can now recognise as a forerunner of the materials that are known to-day under the generic name of Plastics. (Those who wish to refer to his paper will find it in the *Journal of the Society of Arts*, Vol. 14, No. 683, for December 23, 1865.) He also said that he had been thinking about the possibility of synthetic materials for twenty years before the gave his paper. Ten years earlier he had taken out the first patent bearing on the celluloid industry.

Alexander Parkes was a Birmingham man, the son of a brass lock-maker, and the fertility of his mind was astonishing. In many ways he resembled those adventurous and speculative scientists of the latter half of the seventeenth century who formed a little club, which ultimately became the Royal Society. The innovating fecundity of his mind found expression in many practical inventions. Before he died in 1890, he had taken out some 80 patents, covering an enormous range of activities, and including metallurgical subjects, electro-plating, nitro-cellulose and celluloid, furnaces, candles, and the ornamentation of metals.

#### American Science at War

The subject of the 1943 Pilgrim Trust Lecture, given at the Royal Society by Dr. Karl T. Compton, director of the Massachusetts Institute of Technology, was "The Organisation of American Scientists for the War". After describing the prostitution of science for war purposes as a grim reminder that the skill of statesmanship had not kept pace with our ideals, he proceeded to explain the way in which scientific research is geared to the American war effort. He mentioned that both the National Academy of Sciences and the National Research Council had been set up in earlier wars; the former in 1863 when Lincoln was president, and the other during the Great War, under President Wilson.

Over 200 committees were now at work under the aegis of the National Research Council dealing with specific subjects such as aviation medicine, passive defence against bombing, and reclamation of tin. In times of emergency it was advisable to set up new organisations for the mobilisation of scientific man-power, and the new "temporary" organisations included the National Roster of Scientific and Specialised Personnel, which kept a register on which there were now some 600,000 names. In all 140,000 names had been certified by the roster to agencies engaged in the war effort. The Office of Scientific Research and Development, under the direction of Dr. Vannevar Bush (president of the Carnegie Institute of Washington) had executive functions; O.S.R.D. research was done through contracts with academic and industrial research institutions, and 1,400 of these contracts had now been put out, engaging the attention

of 6,000 scientists and engineers. The most recently formed committees were the Joint Committee on New Weapons and Equipment—with Dr. V. Bush as chairman, and including the Assistant Chiefs of Staff of the Army and the Navy—and the new department set up to deal with production methods and substitute materials.

Technical officers for the armed forces were being trained at the rate of 250,000 a year by 1 to 4 year courses at the universities and technical institutions. Dr. Compton concluded by saying that when victory had been won and the whole story of war-time scientific accomplishments could be told it would indeed be a thrillingly interesting recital. Out of it would come not only an important contribution to victory, but also a number of significant results of permanent peace-time value which would help to compensate for the ravages wrought by the war.

#### Prof. E. T. Whittaker's Guthrie Lecture

THE 27th Guthrie Lecture of the Physical Society was given by Professor E. T. Whittaker, F.R.S., on May 18, 1943. The lecture was devoted to a study of the association which has been held to exist between the philosophical theory of determinism on the one hand, and the scientific view of the world, on the other.

When a coin is tossed, the lecturer said, we say that whether it comes down heads or tails is a matter of "chance". This does not mean that there is any real indeterminism in the occurrence, but merely that we cannot make a confident prediction because we do not know the precise velocities of translation and rotation which were communicated to the coin by the thumb of the operator, or the exact mass and figure of the coin, or the density and resistance of the air. If these, and the other relevant data which are unknown to us, are called the "hidden parameters", then an imaginary person to whom the values of the hidden parameters were correctly known, would be able, by aid of the laws of dynamics, to calculate mathematically all the circumstances of the flight and to determine whether the coin will fall heads or tails. Phenomena of this kind, which are in reality deterministic, although we cannot foretell their outcome because of our lack of information regarding hidden parameters, may be called "crypto-deterministic". Wherever the notion of "chance" occurs in classical physics, it has the crypto-deterministic sense. It is otherwise in the newer atomic physics. The alpha-particles emitted by a small quantity of radium salt may be observed by means of the scintillations they produce on a fluorescent screen, and these scintillations appear at irregular intervals—it is impossible to predict the instant when any particular radium atom will explode. By a quantum-mechanical examination, the lecturer showed that this phenomenon cannot be crypto-deterministic, but involves a true indeterminism. Thus the world is not a closed deterministic system but experiences a continual succession of intrusions or fresh creations.

#### Personal Pars

At the annual general meeting of the Physical Society held on May 18 the following officers were elected for the year 1943-44: *President*, Prof. E. N. da C. Andrade; *Vice-Presidents*, Dr. J. H. Brinkworth, Prof. C. D. Ellis, Dr. H. T. Flint, Prof. N. F. Mott; *Treasurer*, Dr. C. C. Paterson; *Secretaries*, Mr. J. H. Awbery (*Papers*), Dr. W. Jevons (*Business*); *Foreign Secretary*, Sir Owen Richardson; *Librarian*, Prof. L. C. Martin; *New Members of Council*: Prof. D. Brunt, Dr. B. Chalmers, Brigadier B. F. J. Schonland, Dr. W. S. Stiles. The Chairman and Secretary of the *Colour Group* are Mr. J. Guild and Mr. H. D. Murray, respectively; and of the *Optical Group* Dr. A. O. Rankine and Prof. L. C. Martin.

At the Annual General Meeting of the Nutritional Society held on May 23, Sir John Orr, the eminent nutritional expert and Director of the Rowett Research Institute in Aberdeen, was re-elected chairman. Dr. L. J. Harris, of the Dunn Nutritional Laboratory, was elected secretary, and Mr. A. L. Bacharach, the vitamin expert, was elected treasurer. From the close voting for membership of the committee, Mr. F. le Gros Clark, Professor S. J. Cowell, Dr. A. P. Meiklejohn and Dr. Lucy Wills emerged successful.

The Chemical Society has elected Professors Linus Pauling, Nikolai Semenov, and Nikolai Zelinsky as honorary fellows. Professor Pauling, aged 42, has been for 15 years professor of chemistry at the California Institute of Technology, and director of the chemical laboratories there since 1937. He has carried out extensive research into the nature of chemical bond by means of wave mechanics, X-ray study of crystals, electron diffraction of vapours, and in other ways. His work has contributed much to modern views of chemical structure. Professor Zelinsky is the veteran Russian organic chemist whose reputation is world-wide. Head of one of the largest chemical schools in Russia, his original contributions have been numerous and of the highest quality. Professor Semenov is also internationally famous. He has been director of the Institute of Chemical Physics at Leningrad since it was opened in 1931. Trained as a physicist, he was led to the study of chemical reactions through his work on the breakdown of insulators under electric discharges. In many ways his work brought problems of combustion, ignition, and explosion within range of simple quantitative treatment for the first time.

Dean C. J. Mackenzie, acting president of the National Research Council of Canada, has arrived in this country and will confer with British scientists on questions of scientific research connected with the war.

Dr. A. C. Chibnall, professor of biochemistry at Imperial College of Science since 1936, has been chosen to succeed Sir F. Gowland Hopkins as Sir William Dunn, professor of biochemistry at Cambridge. Prof. Chibnall, who is 49, is an authority on proteins.

Mr. G. D. Preston, Senior Scientific

Officer, National Physical Laboratory, has been appointed to the Harris Chair of Physics, University College, Dundee. Mr. Preston has been at the N.P.L. since 1921 and has been particularly interested in the study of metals and alloys by X-ray diffraction; recently, he has been concerned in the development of the electron microscope.

Sir Harold Hartley has been appointed general treasurer of the British Association in succession to Professor P. G. H. Boswell, who has resigned after twelve years in office, first as general secretary and then as general treasurer.

Professor R. G. W. Norrish has been nominated as president of the British Association of Chemists for 1944.

#### Honour for Sir John Russell

SIR JOHN RUSSELL, who retires from his post as director of Rothamsted Experiment Station this year (the change coincides with the centenary of Rothamsted) has been awarded the Albert Gold Medal of the Royal Society of Arts. This award was announced last month at the R.S.A. meeting at which Sir John summed up the series of lectures on "Agriculture To-day and Tomorrow". The president of the society said it was likely that the medal would be inscribed "For his services to agriculture in many lands and notably for his researches in soil science". The Minister of Agriculture, Mr. R. S. Hudson, who also was present, congratulated Sir John Russell and said that the public at large must be made to realise that the soil of Britain was a priceless heritage.

Sir John said there was a striking difference between the countryside of to-day and that of 10 years ago. It was hoped that farmers after the war would be able to make as noble a contribution to reconstruction as they were now making to the war. We could aim at ensuring the maximum degree of national self-sufficiency, or at the optimum nutrition for the largest number of our people. If this war ended in such a way that it was but the prelude to others and worse, then we should have no option but to aim at self-sufficiency. If, on the other hand, freedom from war could be ensured for a generation or two maximum nutrition could be the aim, and he assumed that this was what would happen. The adoption of a nutrition policy meant that we should concentrate on the production of foods rich in vitamins and mineral matter; protective foods like milk, eggs, vegetables, and fruits; good quality meat, poultry, and so on. It was not possible to devise a water-tight agriculture policy for ourselves alone. Our agriculture was inextricably bound up with that of other countries. The decision did not rest entirely with us, but with Europe and the U.S.S.R. A policy of peace and plenty would enable international trade to start on a sound basis.

#### A.Sc.W. Membership

THE Annual Council meeting of the Association of Scientific Workers was held at the St. Martin's School of Art, Charing Cross Road, London, on May 8 and 9.

The annual report, which was adopted, stated that the A.Sc.W. has doubled its membership during the year. There are now 11,132 members organised in some 140 branches.

#### Artificial Insemination in the British Empire

INFORMATION that artificial insemination has been practised for some years in Kenya was recently given in the House of Commons by Colonel Stanley. Experiments are still being conducted in Kenya with a view to extending operations over wider areas than are at present possible under existing climatic conditions. Sir Frank Stockdale, said the Colonial Secretary, has proposed that artificial insemination should be undertaken in certain of the West Indian Colonies in order that the improvement of stock, particularly dairy herds, may be accelerated. So far as is known no subsidies are given for artificial insemination, but facilities are provided by the Government in Kenya.

The latest edition of Bulletin 39 (*Fertility and Animal Breeding*; F. H. A. Marshall and John Hammond) just published by the Ministry of Agriculture, recommends artificial insemination as an effective method of livestock improvement under suitable conditions and under proper control. It is here stated that "contrary to what is sometimes thought by those who have no experience of the method, the young as a result of artificial insemination are just as well grown and healthy as those from a normal mating". From the same source we learn that the first artificial insemination experiments were carried out as long ago as 1780, while the practice was carried on by the Arabs for their horses in olden times.

It is considered that ten cows can be impregnated with semen from one ejaculation of a bull, and that two bulls can supply enough semen to inseminate about 4,000 cows a year. Lambs have been produced in Poland from semen collected from a Suffolk ram in Cambridge, and calves have been born in England from a Friesian bull's semen that was collected in Holland and sent over by post in a thermos flask at low temperature. In some countries—Russia, U.S.A., and Denmark, for instance—societies have been formed so that members can obtain semen for artificial insemination from a first-class male.

#### A new German Food Yeast

THE Germans are producing food yeast. The yeast, *Torula utilis*, is reported as being grown on hemicelluloses derived from plant fibres used in making artificial textiles in the presence of phosphates and ammonium salts. This food yeast, which is rich in vitamins B<sub>1</sub> and B<sub>2</sub> is fit for animal and even human consumption. The Phrix Werke A.G. reports that in one of the larger cell-wool plants 50 to 60 tons of yeast can be produced a day, and with the present production of chemical fibres in Germany it is therefore estimated that 100,000 tons of pure protein (food yeast contains 50% protein) could be made from this source, which had previously been almost neglected.

#### Science and Milk Bottle Caps

TWO scientists of the London School Hygiene have been investigating relative merits of different types of bottle caps from the point of view of hygiene. Dr. Betty C. Hobbs and Dr. S. Wilson (*Journal of Hygiene*, 1943 (43, p. 96) criticise the ordinary wide-mouth bottle with a press-in disc cap because it is peculiarly susceptible to contamination from human and animal sources, they say it should not be allowed, unfitted with a hooded cap. In its place they suggest there should be used either a narrow necked bottle, so designed to minimise the contact of milk with the outside of the neck during the operation of pouring and closed a deep press-on aluminium cap covering the rim, or a single-service paper board container. They also criticise many milk bottle washing machines in use as having been designed by engineers and being operated by technicians without any strict regard for bacteriological principles.

#### Hormones in Sewage

ACCORDING to recent American reports sewage and sewage sludge have been shown to contain hormones which stimulate plant growth such as indole, skatole, indole-acetic acid and naphthalene-acetic acid. These hormones have not yet been extracted, but the stimulating effect of sewage on plant growth is partly ascribed to them.

#### Electrostatic Grading

AN "electrostatic grading" process for sorting small flake mica according to the thinness of the flakes has been developed by the U.S. Bureau of Mines. The mica is placed on a shaking table and subjected to charges from a grid electrode above and parallel to the table. The thinnest flakes are most buoyed by the electrostatic force, and are thus separated from the thicker flakes.

#### Dyes and Cabbage

OWING to the shortage of coal tar dyes Nazi chemists are reported to be producing colours from red cabbage. The dye passes under the name of "Caulene", which is the base of a series of blue and green derived colours.

#### Airborne Diseases

BEFORE the war great anxiety was expressed at the possibility of disease germs being spread by insects carried in transport planes. A great deal of attention was given to the problem in America, and it is now reported that chemical methods have been found effective in controlling the diseases. Sodium hypochlorite and propylene are extensively used, while ultra-violet radiation from mercury-vapour lamps placed 8 feet above the plane floor has also been tried with success.

#### Industrial Health Research

THE Medical Research Council is to establish at the London Hospital a department for research in industrial medicine with Dr. Donald Hunter, physician to the hospital, as director.

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